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REPORT

UPON METHODS FOR

INCREASING THE CAPACITY

AND

REDUCING THE NOISE

OF THE

UNION ELEVATED RAILROAD OF CHICAGO

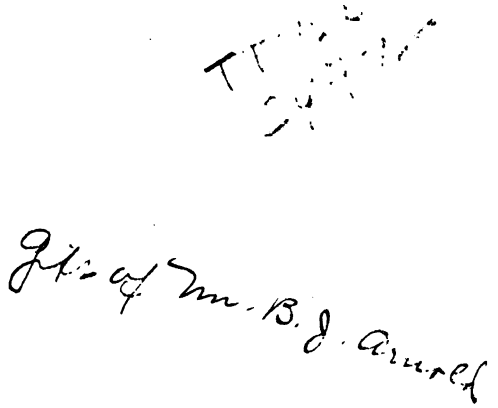
SUBMITTED TO

THE COMMITTEE ON LOCAL TRANSPORTATION OF THE CHICAGO CITY COUNCIL

BY

BION J. ARNOLD

MARCH, 1905



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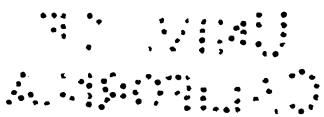

LETTER OF TRANSMITTAL.

To the Honorable Chairman and Members of the Committee on Local Transportation of the City Council of the City of Chicago:

Gentlemen—I have the honor to present herewith a report showing the result of my investigations relating to the practicability of increasing the present capacity of the Union Elevated Railroad of Chicago and possibility of reducing the noise caused by the operation of trains over it.

A perusal of the report will show that the capacity of the loop can be doubled by adopting the recommended plan provided joint operation of the different elevated roads of the city can be effected and that the noise can be greatly reduced by improving the track and rolling stock. The report will also show that the noise can be still further reduced by adopting other methods which affect the road bed and structure although to what extent some of these methods will prove effectual can only be determined by actual trial.

In considering the methods for increasing the capacity of the loop I have endeavored to not only outline one plan, which to me seems best, but to submit several plans each of which accomplishes certain objects and from among which there can be selected a plan, that can be agreed upon, which will permit the independent operation of the roads, as at present, and make it practicable to through route when, through unification of the roads or otherwise, this method of operation can be effected.

In closing I desire to acknowledge the valuable assistance rendered me in the preparation of this report by Mr. J. B. Strauss, C. E., and Mr. George Weston, C. E., and to thank the officials of the different elevated railroads of this and other cities and of various steam railroads for valuable information furnished.

Respectfully submitted,

Bion J. Arnold

328846

Consulting Engineer.

Chicago, March 7th, 1905.

UNIV. OF CALIFORNIA

PART I.

DISCUSSION OF THE PRESENT ELEVATED LOOP AND SUGGESTED MODIFICATIONS FOR INCREASING ITS CAPACITY, AND TO PROVIDE FOR THE THROUGH ROUTING OF CARS OF THE ELEVATED RAILWAY SYSTEMS.

In analyzing this subject it will probably facilitate matters to quote certain portions of my report submitted to the Local Transportation Committee of the Chicago City Council, November, 1902, relating to the Union Elevated Loop, as follows:

"The Union Elevated Loop, which encircles the business district of Chicago, is a two-tracked railroad two miles in length, and it serves as a terminal for the traffic coming from practically seven different elevated railroad lines. The Metropolitan West Side Elevated brings in over the four-track structure east of Marshfield Avenue the traffic from its four double-track branches. The traffic from the South Side Elevated road, as well as that from the Lake Street (name since changed to Chicago and Oak Park) and the Northwestern Elevated lines, is operated over this two-tracked structure simultaneously with the traffic coming from the Metropolitan lines.

No less than 1,600 trains ranging from two to five cars in length are delivered to the Loop Railroad daily. The total number of cars operated on the loop per day is 5,000. The traffic of the elevated railroads, like that of the surface lines which terminate in the business district, is principally handled during ninety minutes in the morning and ninety minutes in the evening. The period of maximum congestion on the loop tracks extends over approximately thirty minutes during the morning and thirty minutes during the evening rush hour. At these times the average headway between trains on the outer loop is 19.8 seconds and on the inner loop 19.5 seconds. *The*

ultimate capacity of the loop tracks is fixed by the number of in-bound and out-bound trains which it is possible to pass through the junctions at Lake Street and Fifth Avenue, Wabash Avenue and Van Buren Streets, and Van Buren and FifthAvenue.

It has been demonstrated that a train of five cars can be successfully and successively passed through one of the junctions from a state of rest to clearance, and the interlocking combinations be operated to open another route for the passage of incoming or out-going trains in 45 seconds of time. If it were necessary to operate the interlocking mechanism for each in-bound and out-bound train, the capacity of these junctions would long ago have been exceeded. It is possible, and in fact is the usual practice, to simultaneously pass an in-bound and an out-bound train from the main line to the loop and vice versa.

CAPACITY NOW LIMITED BY STATION PLATFORMS.

As previously stated, the ultimate capacity of the present double-tracked loop is limited to the maximum number of trains which it is possible to pass in all directions through the junction points, and moreover, the capacity of the junctions cannot be increased. Under existing conditions, however, it is *the station platforms* on the loop and *not the junctions* which limit the number of trains that can be operated over its tracks.

These platforms are much too short to admit of trains being operated at intervals and speeds which will equal the capacity of the junctions. They should be lengthened sufficiently to permit two trains, of five or six cars each, to simultaneously occupy a platform. If the junctions were operated to their maximum capacity, the longest time to be consumed by a train in making one complete circuit of the loop should not exceed fifteen minutes. Under the existing conditions, during the hours of maximum traffic, the average time consumed by a train in making a complete circuit of the loop is twenty minutes. To anyone who will take the trouble to observe the movement of trains on these tracks any day between the hours of 5:30 p. m. and 7 p. m., the reason for this loss of time in making a round trip of the loop will become apparent. He will find that the headway, or spacing, of the trains on both tracks cannot be materially reduced. In other words, he will find crowded on these tracks at that time the maximum

number of trains consistent with safe operation. He will also discover that the movement of every train is very much retarded at each station because it is prevented from approaching the platform until the preceding train has taken on its load of passengers and is under way leaving the station. There are eleven stations on the loop at which all trains stop, and, under the conditions above described, it is obvious that each train must be retarded and accelerated twenty-two times, instead of eleven times, as would be the case if the train could approach the station platform without having to wait for the train preceding it to move out of the way. It is the frequent starting and stopping of the trains which regulates the time schedules in the operation of the elevated railroads. The average distance between the loop stations is less than 955 feet, and it is evident that under the most favorable conditions, most of the time consumed in making a circuit of the loop is taken up in accelerating and retarding the trains, and when these operations are multiplied by two, the efficiency of the loop as a terminal is very materially reduced. The actual loss in efficiency is very closely represented by the difference in time required for a train to complete the round trip. As shown by the foregoing statements, this difference in time is approximately 25 per cent.

In respect to the ability of the junction mechanism to handle additional traffic, observation indicates that it has ample capacity to care for any increased efficiency of the loop which may be created by the extension of stations platforms."

* * * * * * "Unless some plan of separate loops is adopted, the only remaining method by which additional terminal facilities can be provided for the elevated railroads after the full capacity of the present junctions has been reached through extension of platforms is by establishing auxiliary stub-terminals outside of the loop and adjacent to the business district.

Should the time ever come when all the elevated railroads were consolidated under one control and passengers were transported within the district served by all of the companies, for one fare, the problem of increasing the loop capacity would cease to be a problem, as the tracks now forming the loop, by slightly changing the present junction points, would become simply sections in through lines that would be operated between the North, South and West divisions. The loop could then

be operated in conjunction with these through lines, as at present, to furnish terminal facilities for any auxiliary service that might be required during the morning and evening rush hours."

With more time for the consideration of the loop question than it was possible to put upon it at the time the above report was prepared, I find that, while the statements made above and the conclusions derived are true, it does not seem that the plan proposed in the last paragraph, if carried to the greatest degree of refinement with respect to through routing, would relieve the congestion on the loop as effectually as though it were only partially carried out.

Therefore, while universal through routing can be accomplished if demanded, the capacity of the loop would not be increased to such an extent as seems necessary; but if through routing to as great a degree as is practicable, or in my judgment necessary, is acceptable, the capacity of the loop and of the roads operating over it can be greatly increased and the present method of operation simplified, as can be seen from the following analysis:

Plate I represents the loop as it is now constructed and operated. The trains of the South Side Elevated Railway and those of the Metropolitan West Side Railway run upon the inner loop track, thus necessitating their crossing, both in-coming and out-going, at points "a" and "b," the outer loop track over which the Northwestern and Oak Park trains run; but it should be noted that these crossings, are so designed that it is practical for trains to pass on to and off from the inner loop simultaneously in case they chance to arrive at their respective loop connecting points at the same time.

From an analysis it will be seen that the point on the loop which now limits its capacity is at "a," where the Metropolitan tracks cross the outer loop track to enter and leave the inner loop at Fifth Avenue and Van Buren Street, where under present conditions of maximum operation 40 in-bound and 40 out-bound Metropolitan trains meet 67 Oak Park and Northwestern trains in one hour.

The next most congested point is at "b," Van Buren Street and Wabash Avenue, where 31 in-bound and 31 out-bound trains of the South Side Road meet 67 Oak Park and Northwestern trains in one hour.

Assuming that it is practicable to pass a train through these

points and clear for another train in 45 seconds, the maximum number of trains that could enter the loop in one hour from either of these points would be 45, providing the interlocking plant had to be worked for each train; but since it is possible for a train to pass off from the loop at each of these points at the same time that a train is also passing on to it, the interlocking device needs to be worked but twice to allow the passage of three trains,—one entering the loop, another leaving the loop, and the third crossing the tracks of the other two, and it is this feature that gives the present junction points their efficiency over any other that can be devised for the present method of loop operation, for it permits three trains to be handled through them in one and a half minutes provided the trains chance to come, or are arranged, in such manner as to utilize this advantage.

It is this fact, in connection with the fact that under present conditions of operation the trains of the different roads become bunched in such a manner as to allow two or more of them to pass through a junction point with but one setting of the interlocking devices, that makes it possible to operate more than 45 trains on and 45 trains off the loop per hour at these points, and gives to the present loop system its high efficiency from an interlocking standpoint, which efficiency must be somewhat sacrificed with any method I am able to devise for through routing the trains between *all* the different sections of the city, although by providing for through service between the North and South Side systems and between the two West Side systems only, the congestion can be reduced, due to the through cars occupying but one-half the loop, and more cars can be operated over the loop per hour than at present. *By elevating the structure at certain points, hereinafter shown, the through routing features could be retained, the grade crossings eliminated, and the capacity of the loop would be increased* 100 *per cent if only through cars were run.* Owing to the difference in the number of trains operated by the different roads, the through routing of all trains is impracticable from an economic standpoint, and, therefore, provision should be made for running such a proportion of the trains of each road around the loop as might be found desirable, in which case the *increased* capacity of the loop would be reduced in the proportion that the loop trains bear to the through trains. By this method of operation, the number of trains required by each road to oper-

ate the present schedule, or any other fixed schedule, would be reduced in proportion as the time saved by the through trains in passing over the loop bears to the time required for a train to make a round trip from any outside terminal and back, when operating over the whole loop, as at present.

At the present time there are in operation on the loop 49 trains during the maximum rush hours, the number being as follows:

Metropolitan	14	
South Side	11	
Total number of trains on inner loop at one time		25
Northwestern	15	
Chicago & Oak Park	9	
Total number of trains on outer loop at one time		24
Total number of trains now operating on both loops		49

The Metropolitan and South Side trains are alloted on the basis of five cars per train, and the Northwestern and Chicago & Oak Park are alloted on the basis of four cars per train.

The maximum train service in one hour, taken from a recent daily record, is as follows:

Metropolitan	40	
South Side	31	
Northwestern	42	
Chicago & Oak Park	25	
Total number trains passing over both tracks of the loop in one hour		138

At the present time these trains are put around the loop during the rush hour period, when everything is working satisfactorily, under average conditions in from 18 to 20 minutes.

During the middle of the day and at other than the rush hour periods, the running time around the loop is from 13 to 14 minutes, thus showing that when fewer trains are operated upon the loop, the running time can be materially cut down owing to the loading facilities then being ample. But, as pointed out in my previous report, about 25 per cent more trains could be put around the loop during the rush hour period under present conditions if additional platform facilities were provided.

The average number of cars per train during the maximum service is as follows:

Metropolitan	4 and 5
South Side	5
Northwestern	4 and 5
Chicago & Oak Park	4

During the month of November, 1904, the number of cars operated around the loop was as follows:

Metropolitan	55,308	
South Side	35,061	
Total cars inner loop		90,369
Northwestern	34,838	
Chicago & Oak Park	20,509	
Total cars outer loop		55,347
Total cars on both loops for month		145,716

The traffic on the loop may be divided into two classes, viz: the congested traffic of the rush hours and the lighter business during the remainder of the day.

The rush hour business is a problem needing immediate attention for all the roads. This business may be divided into two classes: First, a traffic to and from the Union Loop in the down-town shopping and general business district; second, a traffic to and from the manufacturing districts on either side of the River. I am informed that 40 per cent of the rush hour business on the Metropolitan road originates from the stations just west of the Union Loop, such as its Fifth Avenue stub terminal, Franklin Street, Canal Street and Halsted Street. A similar condition exists with reference to the other roads although the percentages will not at present be so great, owing largely to the lack of stub-end terminal facilities for the Northwestern and the fact that the Oak Park road does not now operate its stub terminal regularly.

In order to handle its business, which does not naturally come to the loop, the Metropolitan Company is operating two systems of trains during rush hours, viz: First, loop trains consisting of five car trains every six minutes from each of its branches, making five-car trains every minute and a half on and off the Union Loop; second, Fifth Avenue trains, consisting of three or four cars, every six minutes from each branch into its Fifth Avenue terminal (Fifth Avenue between

Van Buren Street and Jackson Boulevard). These Fifth Avenue trains operate only during the rush hours and give one and one-half minute intervals out of this terminal. The Fifth Avenue system of trains has now been in operation about five months, and I understand has effected a great relief to the overcrowded loop trains on the road, thus demonstrating that a large percentage of the Metropolitan passengers are travelling to and from the district west of or close to the southwest corner of the loop.

The South Side road is also operating some trains into its terminal at Congress Street, and it would thus seem that if similar stub-end terminals were developed for the other roads at present operating around the loop, a great relief could be effected, both to the patrons of the roads and the railway companies, provided these stub-end terminals could be conveniently located.

The perfection during the past few years of power mechanism for operating switches and signals at junction points has been such as to warrant its adoption on the loop and if used the capacity of the junctions could be somewhat increased owing to the quicker action of the mechanism. When the advantages of this improvement and of the use of "the multiple unit-system" on the cars are utilized, I know of no way that the capacity of the loop, as now built, can be increased under the present method of individual ownership operation except by extending the platforms, and when this is done, relief to the present loop district must come from the development and operation of stub-end or other terminals for each road, unless unification or some method of joint operation can be effected whereby through routing can be adopted, as hereinafter described.

Plate II shows a plan of changing the present elevated loop structure and connections in such a manner as to permit the through routing of trains from any one of the three main divisions of the city to any other division. Under this arrangement it would be possible to run trains from the South Side to the North Side and back; from the South Side to the West Side over the Metropolitan Road, and from the South Side to the West Side over the Oak Park road, and from each of these roads to the South Side. It is also possible to run trains from the West Side over either the Metropolitan or the Oak Park roads to the North Side and back, and is submitted as a possible plan for universal through routing, although it does not

relieve the present congestion on the loop or permit the increasing of its capacity on account of the many trains that must intersect each other at the junction points. This plan necessitates the utilization of both the inside and outside tracks of the loop for the different roads, and this would tend to bewilder passengers in locating their proper trains. It would also necessitate reversing the direction of the operation of the trains on the Northwestern and Oak Park roads from left-hand running to right-hand running, but would leave the Metropolitan and South Side roads running right-handed as at present. Under this plan, a North bound through train starting from the South division of the city would run on the outside loop north on Wabash Avenue, west on Lake Street, thence around the curve shown to the right-hand track of the Northwestern road. Returning from the North division of the city, it would come south on the outside Fifth Avenue track of the loop and east on the outside Van Buren Street track, thence south on the west track of the South Side road.

A through train from the South Side to the West Side over the Metropolitan road would start from the east track of the South Side road, pass around the curve at Wabash Avenue and Van Buren Street, leading on to the inside or north track of the loop on Van Buren Street, thence west and out on the north track of the Metropolitan road. Returning this train would come from the south track of the Metropolitan on to the south track of the Van Buren Street side of the loop, thence south on the west track of the South Side road.

A through train bound from the south division to the West division of the city over the Oak Park road would run over the east track of the loop on Wabash Avenue, thence west on the north track on Lake Street, and out on the north track of the Oak Park road. Ruturning it would come from the south track of the Oak Park road east on the south track of the Lake Street section, and south on the west track of the Wabash Avenue section of the loop, thence out on the west track of the South Side road.

A through train originating on the Metropolitan road bound for the North Side would pass from the south track of the Metropolitan road around the curve at Fifth Avenue and Van Buren Street, thence north on the east track of the Fifth Avenue section of the loop and out on the east track of the Northwestern. Returning it would come from the West track

of the Northwestern, south on the west track of the Fifth Avenue side of the loop, thence west on the north track of the Metropolitan.

A train originating on the Chicago & Oak Park road bound for the north part of the city would pass from the south track of the Oak Park road around the curve at Lake Street and Fifth Avenue, north on the east track of the Northwestern. Returning it would come south on the west track of the Northwestern around the curve and west on the north track of the Chicago and Oak Park road.

It will be seen that it is also possible to operate trains from each of the roads around the loop in addition to the through trains just described: All loop trains of the South Side and Northwestern roads keeping the outside tracks of the loop, while the loop trains of the Oak Park and Metropolitan would keep the inside track of the loop.

A close analysis of this system will show that the traffic crosses itself many times, and an examination of the sketch will show these points. For illustration assume a schedule based upon the same number of trains operating over the loop as are at present operating, and distributed as follows:

Through trains per hour from South Side to Northwestern	9
Through trains per hour from South Side to Metropolitan	9
Through trains per hour from South Side to Chicago & Oak Park	9
Trains per hour from South Side Road around the loop and back to the South Side	6
Total South Side trains per hour	33
Through trains per hour from Northwestern to South Side Road	9
Through trains per hour from Northwestern to Chicago & Oak Park	9
Through trains per hour from Northwestern to Metropolitan	9
Trains per hour from Northwestern Road around loop and back to North Side	18
Total Northwestern trains per hour	45

Through trains per hour from Oak Park to Northwestern 9
Through trains per hour from Oak Park to South Side 9
Trains per hour around loop and back to Oak Park Road 9

Total Oak Park trains per hour.....27

Through trains per hour from Metropolitan to South Side Road..... 9
Through trains per hour from Metropolitan to Northwestern 9
Trains per hour around the loop from the Metropolitan and back to the Metropolitan.....24

Total Metropolitan trains per hour.....42

The trains would then meet and cross each other per hour as follows:

CORNER OF WABASH AVENUE AND VAN BUREN ST.

At Point.			
a	9 Oak Park South Side trains	meet	18 N. W. Loop trains
b	do.		9 S. Side-Met. trains
c	18 Northwestern Loop trains	meet	9 S. Side-Met. trains

CORNER OF VAN BUREN STREET AND FIFTH AVE.

d	24 Metropolitan Loop trains and 9 S. S.-Metropolitan trains	meet	24 Metropolitan trains and 9 Met.-N. W. trains
e	do.	meet	6 S. Side Loop trains 9 N. W.-S. S. trains and 18 N. W. Loop trains
f	9 Met.-Northwestern trains and 24 Metropolitan Loop trains	meet	6 S. Side Loop trains 9 N. W.-S. S. trains and 18 N. W. Loop trains

CORNER OF FIFTH AVENUE AND LAKE STREET.

g	9 Oak Park-South Side trains and 9 Oak Park Loop trains	meet	9 Oak P. Loop trains
h	9 Oak Park-S'th Side trains and 9 Oak Park Loop trains	meet	18 N. W. Loop trains 9 N. W.-S. S. trains and 9 N. W.-Met. trains
j	do.	meet	9 Met.-N. W. trains
k	do.	meet	6 S. Side Loop trains
m	9 S'th Side-Oak Park trains	meet	9 O. P.-N. W. trains
n	do.	meet	9 N. W.-S. S. trains 9 N. W.-Met. trains 18 N. W. Loop trains
o	do.	meet	9 Met.-N. W. trains
p	9 Oak Park-Northw'n trains	meet	9 N. W.-S. S. trains 9 N. W.-Met. trains 18 N. W. Loop trains
s	9 Oak Park-Northw'n trains	meet	9 Oak P. Loop trains
x	9 Oak Park Loop trains	meet	9 N. W.-S. S. trains 9 N. W.-Met. trains 18 N. W. Loop trains
y	do.	meet	6 S. Side Loop trains
z	8 South Side Loop trains	meet	9 Met. N. W. trains

From an inspection of this table it will be found that the most complication occurs at the Fifth Avenue and Lake Street junction, where any single train passing from the Oak Park Road on to the loop or from the Northwestern Road on to the loop, or vice versa, would block the traffic at from four to five points. Thus a train passing from the Oak Park track

on to the loop would block points g, h, j, k and l. This would result, at times, in great congestion at this point; and, therefore, the plan is not one which will tend to effectually increase the capacity of the loop, although it does accomplish through routing from any main division to all other main divisions of the city. It would also materially increase the noise at this junction point, due to the increased amount of special work required. This plan, if adopted, would necessitate the construction of stub-end terminals for all roads and the diverting of some of the present traffic to these terminals, and for this reason a proposed stub-end terminal is shown for the Northwestern Road. This terminal is shown on La Salle Street as this street is now occupied by a tunnel used for surface car operation, and it is thought that the addition of an elevated structure would be less objectionable here than elsewhere, although it could be placed on any other street.

From the preceding it does not seem to me advisable to attempt to apply the through routing principle to the elevated roads as thoroughly as it might be applied to the surface roads, or to the elevated roads were there more elevated tracks laid through the business district. Consequently, the plan shown on Plate III has been developed, which provides for through routing to as great an extent as seems practicable or desirable with the present structure.

In this plan provision is made for routing through trains from the South Side Road to the Northwestern Road and back, and from the Metropolitan Road over the Union Loop to the Chicago & Oak Park Road and back, and at the same time it makes provision for the operation of loop trains for all the roads. It places the trains of the South Side and Northwestern roads on the outside loop track, and the trains of the Metropolitan and Chicago & Oak Park roads on the inside loop track. It also reverses the running of the trains of the Northwestern road to right-hand running, and those of the Metropolitan road to left-hand running. The routing of the through trains under this system would be as follows:

A train originating on the South Side road would run north on the east track of the Wabash Avenue section of the loop, thence west on the north track of the Lake Street section of the loop, thence north on the east track of the Northwestern road. Returning it would run south on the west track of the Fifth Avenue section of the loop; thence east on the south

track on Van Buren Street and south on the west track of the South Side road, thus intersecting traffic on the Metropolitan road at points a and the Oak Park Road at points b and c, as at present.

A train originating on the Metropolitan road would enter the loop on Van Buren Street from the north track of the Metropolitan road, thence north on the east track of the Fifth Avenue section of the loop, thence west on the south track of the Chicago & Oak Park road. Returning it would run east on the north track of the Chicago & Oak Park road, thence east on Lake Street on the south track of the loop, thence south on the west track of the loop on Wabash Avenue, thence west on the north track of the loop on Van Buren Street, and out to the South track of the Metropolitan.

Suitable curves are provided at Van Buren Street and Wabash Avenue and Fifth Avenue and Lake Streets on the outside loop track to allow the operation of loop trains for both the South Side and Northwestern systems, while similar curves are provided at Fifth Avenue and Lake and Fifth Avenue and Van Buren Streets on the inner loop track to allow the operation of loop trains of both the Metropolitan and Chicago & Oak Park Roads.

This plan gives all the advantages of the present system of operation and all necessary advantages of through routing, and at the same time reduces the congestion on the loop, or increases the capacity of the entire elevated railway systems up to the full capacity of the junction points—an increase of not less than 25 per cent over its present capacity, and if power operated junction point mechanism is employed a further increase will be effected.

It would necessitate the changing of cars for passengers desiring to go from either the South or the North divisions of the city to the West Side, and vice versa, but inasmuch as all roads could operate a certain portion of their trains around the loop, all stations could be made transfer stations, thus avoiding congesting the people at a few transfer points, and with a suitable transfer system would give to the citizens the best elevated service possible with the present elevated loop structure when using grade crossings.

In order to eliminate the noise and danger due to grade crossings and to increase the capacity of the entire system of elevated roads of the city to the greatest possible extent

with the present loop structure, the plan shown on Plate IV is submitted as *the best possible solution known to me of the entire problem.* It is the same as the plan shown on Plate III except that the crossings are eliminated by elevating the tracks of the inner loop over those of the outer loop at Fifth Avenue and Lake Street, and the outside track of the loop over the Metropolitan tracks at Fifth Avenue and Van Buren Street. The routing of the cars would be the same as in the case shown in Plate III, but the capacity of the systems would be limited only by the facilities for loading and unloading on the loop structure. Assuming that all trains operated were through trains, the capacity of the present loop and of the roads connected therewith would be increased *one hundred per cent,* and by extending the platforms, thereby permitting increased facilities for loading and unloading, the capacity would be still further increased, and thus *the advantages of the entire elevated and loop systems utilized to their possible maximum capacity.*

If then, each road should be allowed a stub-end terminal, its rush hour capacity could be still farther increased, so that the only limit to the capacity of the elevated roads of the city would be determined by the number of main line tracks leading away from the terminals. I am informed by the officials of the different roads that each road is now capable, so far as the main lines are concerned, of operating at least double its present number of trains, and it will thus be seen that if *through routing and elevating* should be adopted as suggested, *the loop would then be capable of handling all the traffic the present double-tracked roads could deliver to it.* Since, however, it will probably be advisable to continue operating a certain proportion of the trains of each road as loop trains, the capacity of the loop for through trains would be proportionately reduced; and as some of the roads now have three or four tracks, the surplus capacity of such roads over a double-tracked road would have to be taken care of outside the loop by stub-end terminals or auxiliary loops.

The plans shown on Plate III and IV provide for the through routing of cars, thus practically making a double-tracked elevated road through the entire city from North to South, thereby tending to lengthen the present business district in the same manner that the two West Side roads will tend to extend it westward.

Should conditions make it practicable to extend the loop by removing the present Van Buren Street structure to Polk Street and building additional structure to properly connect with it, thereby greatly extending what is known as the "Loop District" it could be accomplished with the least amount of elevated track if built in accordance with the plan shown on Plate V. This plan possesses all of the advantages of the plan shown on Plates III, IV and V. The terminals would then have a larger proportion of their cars in use on the loop owing to its increased size.

Since it is probably impracticable, for business reasons, to remove the present Van Buren Street structure the plan shown on Plate VI is submitted as one which would best combine the advantages of the plan shown on Plates IV and V and leave the present loop as it is now located.

Should this plan be ultimately adopted it would necessitate reversing the direction of running the trains from the one shown on Plates III, IV and V. The terminals would then be of sufficient capacity to accommodate four main line tracks from each road.

This plan would permit the immediate improvement of the present loop, in order to increase its capacity, and permit the extension of the business district at any future time by adding supplemental loops as shown by the dotted lines on the plan.

Its capacity could be increased by adding an additional track on Van Buren Street, Lake Street and Fifth Avenue, but since this is impracticable it is shown with a proposed development of the auxiliary terminal for each road worked out in such a manner as to give maximum efficiency in operation consistent with the least amount of track upon the streets occupied by the present loop. If, on account of the inability of adopting the plan shown on Plate V it becomes necessary to develop the auxiliary terminal idea the plan shown on Plate VI should give the best results to both the public and the railroad with the least objections of any plan I am, at present, able to devise for increasing the loop district.

Its capacity would be greatest with the structure elevated at places as shown in Plate IV but should it be found inadvisable to elevate the tracks it could be used in conjunction with the plan shown on Plate III in which case its capacity would be limited only by the junction points although it would then be greatly in excess of the capacity of the present loop.

It should be noted that on all plans calling for the tracks

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Page 20, eighth line from the top, after "The", substitute "companies" for "terminals".

of the loop to be elevated, the grades have been kept well within the limit for safe operation as the maximum grades are 1½ per cent while in front of stations all grades have been reduced to ½ of 1 per cent for a distance of 500 feet, thus giving ample room for two trains in case the platform should be extended. On the latter grade a train will stand without the brake being applied and is the grade often used by railways

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Page 20, eighth line from the top, after "The", substitute "companies" for "terminals".

[illegible] portions of the loop proper than they would under the plan of partial through routing, thus tending to congest the loop and defeat, to a certain extent, the object sought by through routing. Furthermore, this plan would necessitate operating trains of all the roads upon both the inner and outer loop tracks, which would tend to bewilder passengers.

Considering the many objections to this plan of through routing, and the method of through routing shown on Plate II, as well as the difficulties of removing the Van Buren Street structure it seems that the best results would be secured by adopting one of the plans shown by Plates III or IV and leaving the matter in such shape that some of the suggestions shown on Plate VI could ultimately be adopted should it be found advisable.

The cost of changing the loop to conform to the above described systems would be about as follows:

Plan shown on Plate II, including necessary changes in special work; new interlocking power mechanism and the extension of platforms, but not including any alteration of present track or structure to reduce noise..	$97,000.00
Plan shown on Plate III, including necessary changes in special work; new interlocking power mechanism and the extension of platforms, but not including any alterations of present track or structure to reduce noise..	80,000.00

Plan shown on Plate IV, including elevation of structure, removing and replacing track on elevated portions, modification of stations and platforms due to elevation; new power mechanism for interlocking plants, necessary changes in special work and the installation of escalators at Clark, Randolph, Quincy and La Salle streets, but not including any alterations of present track or structure to reduce noise.....500,000.00

Summarized then my recommendations for increasing the capacity of the loop are as follows arranged in the order of their merits in general and in sub-classification:

First:

a. Reconstruct, elevate and through route in accordance with plan shown on Plate IV.
b. Extend the platforms.
c. Develop the stub-end or auxiliary terminals.

If it is found impracticable to elevate, then:

Second:

a. Reconstruct and through route in accordance with plan shown on Plate III.
b. Extend the platforms.
c. Develop the stub-end or auxiliary terminals.

If on account of the diversified ownership of the roads, or for any other reason, it is found impracticable to secure through routing, then:

Third:

a. Leave the loop as it is now and install power mechanism for operating the switches and signals at the junctions.
b. Extend the platforms.
c. Develop the stub-end or auxiliary terminals.

PART II.

ANALYSIS

OF THE

CAUSES OF THE PRESENT NOISE

AND

DISCUSSION OF DIFFERENT METHODS SUGGESTED FOR REDUCING THE NOISE UPON THE UNION ELEVATED LOOP.

The question of deadening or reducing the sound on metallic elevated railway structures has been a serious one ever since such structures have been put in operation, and though public remonstrance has been great at times, and some experiments for reducing the noise have been made, but little has been accomplished which can be accepted as definitely pointing toward a satisfactory solution of this trying problem, although recent methods of using concrete have made the solution more likely.

The first elevated railroad company to meet criticism of this nature was the Manhattan Elevated of New York, and a number of experiments were made by this Company between the years 1871 and 1878 in an endeavor to find some method of reducing the noise caused by the operation of trains on its elevated metal structure. Many schemes were proposed by various individuals whose theoretical considerations had led them to believe that a practical demonstration of their ideas would solve the problem.

Most of the schemes proposed were methods for supporting the rail upon some cushioning material, such as lead, felt, or asphalt, while others proposed to not only support the rail in this manner, but also to surround it with some substance such as sand, asphalt mixed with sand, crushed stone, felt, lead, etc. Almost all those who offered solutions

seemed to think that some method of shrouding the rail and providing a cushion between it and the structure would prevent the difficulty.

Figures 1, 2 and 3 show some of the most meritorious schemes proposed. These were tried, with others, but it was found that the deadening effect on the noise was not sufficient

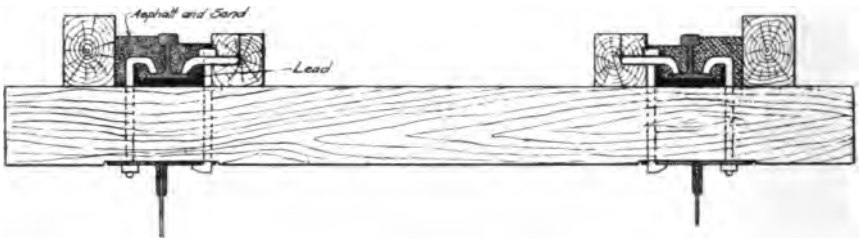


FIGURE 1.

Manhattan Railway Experiment, Showing Rails Surrounded with Asphalt and Resting upon Lead Strips Carried in Steel Channels.

to warrant the expenditure necessary to put the plans into execution over the system and experiments were abandoned.

When the New York Central & Hudson River Railroad Company completed its steel viaduct extending from the Harlem River to 110th Street in 1897, where its trains enter the city of New York through one of the most densely populated

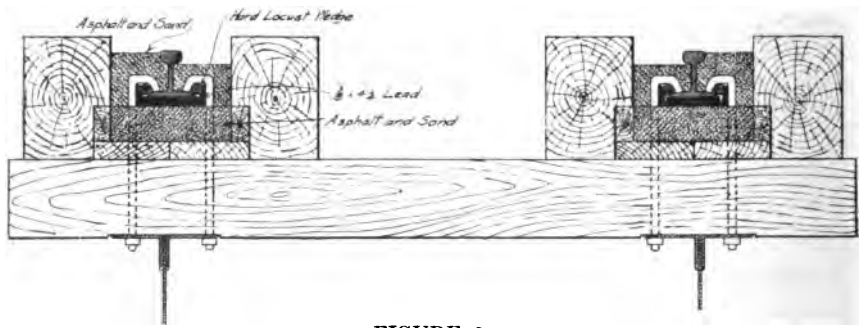


FIGURE 2.

Manhattan Railway Experiment, Showing Same as Figure 1 Except that Steel Channels Rest upon Asphalt.

districts of the city, it was soon confronted with damage suits on the part of the people, due to the excessive noise made by trains running over its track on this steel viaduct. The Company's engineers went into the subject thoroughly at the time, and, after experimenting to a considerable extent with various substances, such as sawdust mixed with asphalt

and other mastic material, came to the conclusion that no such material placed around the rails and under the ties would effectually overcome the difficulty, for while they deadened the noise somewhat, they were not strong enough to hold the track. Figure 4 represents a longitudinal section of this structure as built at the time it was first put in operation. It will be noticed that the rails were clamped rigidly to the steel deck plates of the structure, thus providing the best possible means for the transmission to the structure of whatever blows or shocks the rails received from the rolling stock. Figure 5 represents a longitudinal section of the same structure after the rails had been raised and provided with sawed ties underlaid with crushed stone ballast, thus

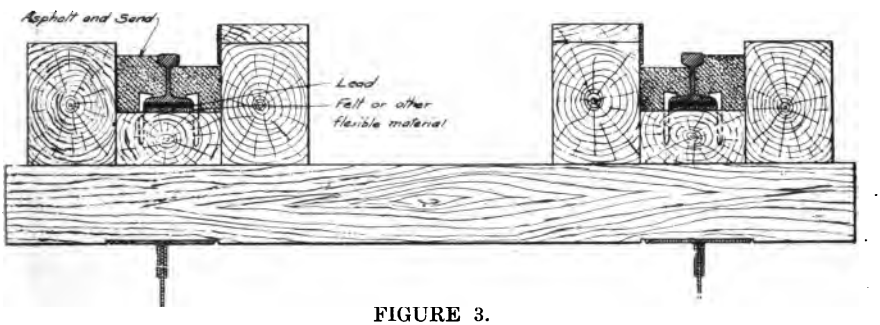


FIGURE 3.

Manhattan Railway Experiment, Showing Rails Surrounded with Asphalt and Resting upon Lead Strips Underlaid with Felt.

making the track similar to the later type of ballasted steel railway bridges and street crossings. The ill effects produced by the operation of the trains were so reduced as to cause the citizens living along the right of way to cease their objections, which resulted in the withdrawal of the damage suits previously brought, thus showing that the remedy applied in this case was somewhat effective, although the noise was only partially eliminated. The structure occupies one of the principal streets in Harlem, and is lined on each side with high apartment buildings. The tracks on leaving the steel structure extend for a considerable distance over a stone viaduct, thence into a tunnel underneath Park Avenue. This case, therefore, offers about the best example of the relative sound deadening effects of four classes of construction that I have been able to find during my investigation, as the trains coming from the North operate

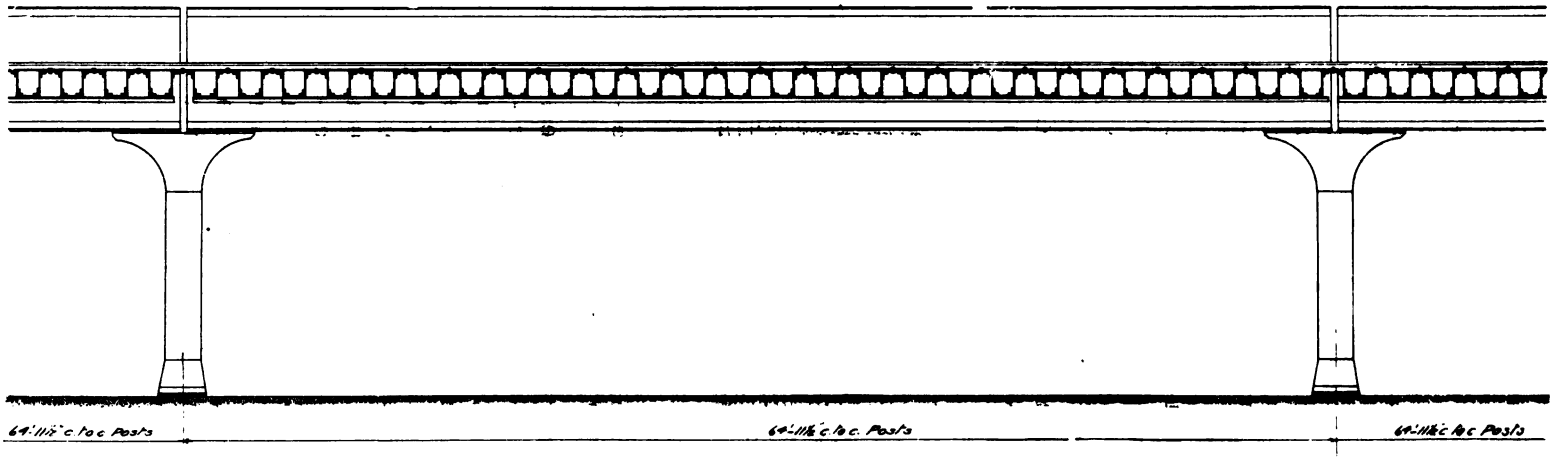


FIGURE 4.
Longitudinal Section of New York Central Viaduct as Originally Constructed with Rails Resting on Steel Troughs.

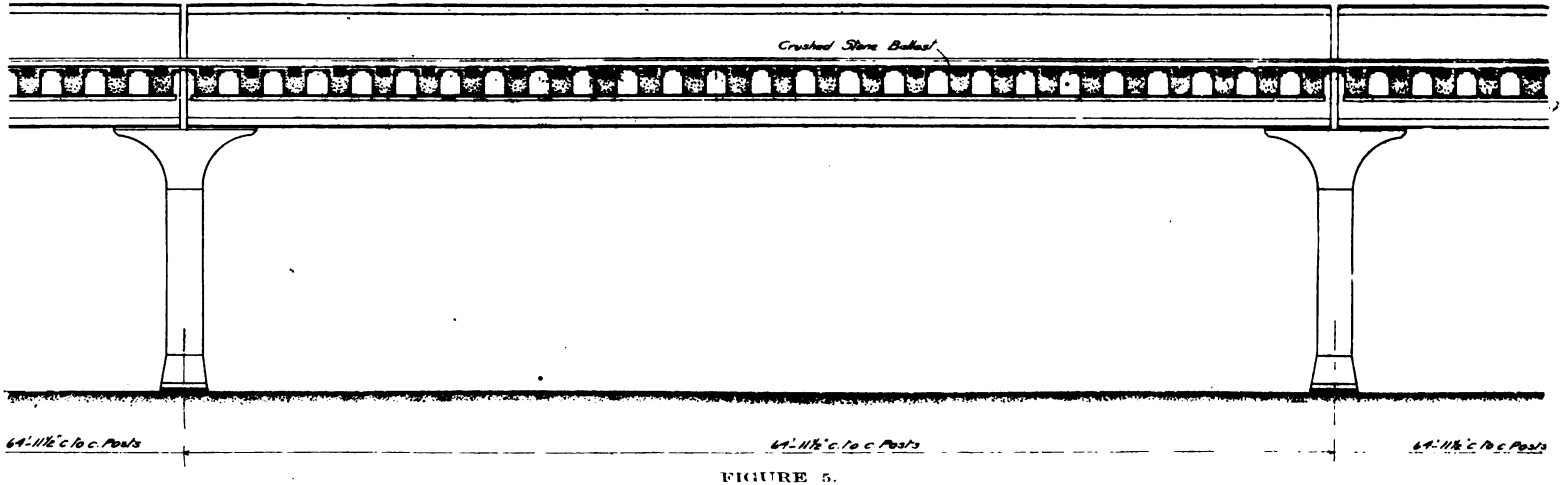


FIGURE 5.
Longitudinal Section of New York Central Viaduct after Ties and Ballast Had Been Put in Place.

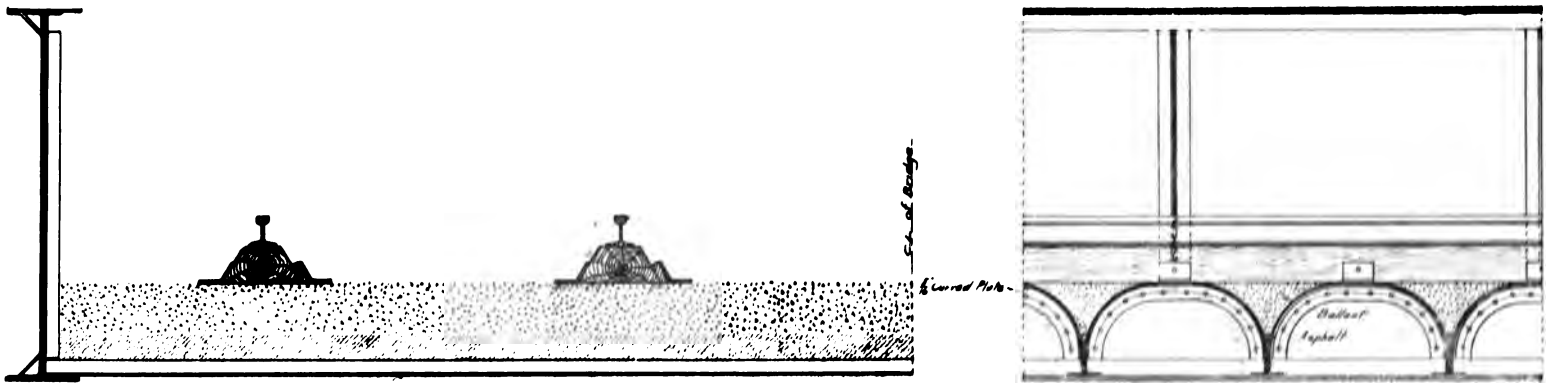
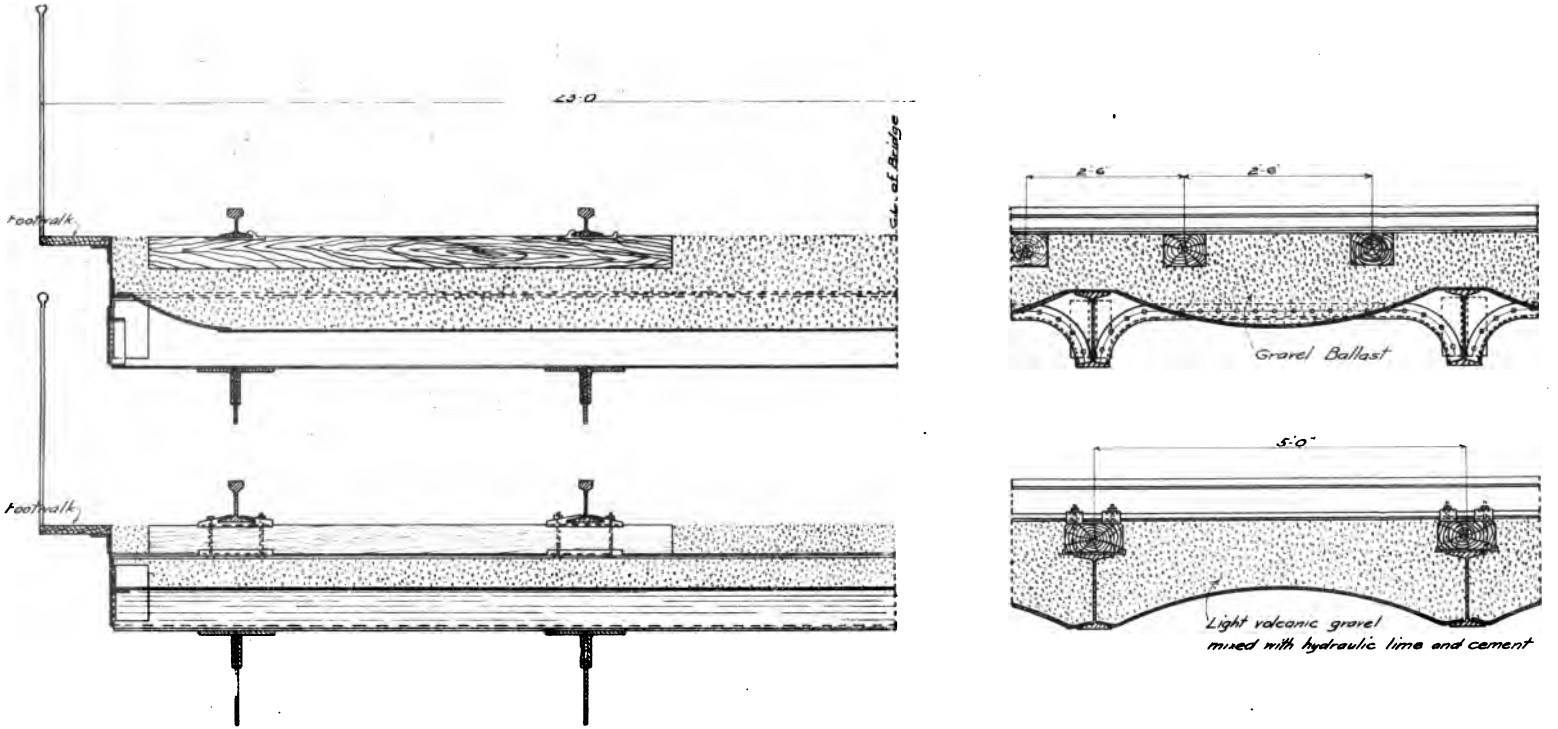


FIGURE 6.
Roadbed of Liverpool Overhead Railway.

first over a steel drawbridge, where the rails rest directly upon the plates of the bridge, then over a rock-ballasted steel viaduct, then over a rock-ballasted stone viaduct, and thence into a tunnel where they are completely surrounded for certain distances and open to the streets at other places. It will be found by one who investigates this case that the noise is greatest on the bridge, less on the steel ballasted structure, considerably less upon the stone viaduct, and if the observer is on the surface of the street over the tunnel where the trains are completely enclosed the perceptible noise is very slight. It will thus be seen that in this case the only place where the objectionable noise is eliminated entirely is where the trains are completely surrounded by a mass of non-metallic and non-vibrating material.

One of the earliest European attempts to deaden the noise on an elevated structure was made on the Liverpool Overhead Railway at Liverpool, England, in 1893. This road was built with a ballasted floor with asphalt and ballast supported on circular steel arches bent from flat plates, in accordance with the type of construction known as Hobson's Arch Plate System. The rails were supported upon longitudinal wooden sleepers, which rested directly upon the arch plates, and the space between these plates was filled with asphalt and ballast. Figure 6 shows this type of construction.

The latest European attempt made in this direction was made in connection with the Elevated Electric Railroad of Berlin, Germany, completed in 1901. This is a rapid transit line, about six miles long, and in both the business and residential sections the construction was intended to reduce the noise, the general design for this purpose embracing a solid floor of buckled plates, filled with a special ballast of volcanic gravel secured from the Rhine Valley. This construction is shown in Figures 7 and 8, and it will be noticed that in Figure 7, which represents the road as constructed in the Western or residential portion of the city, the ties are embedded in ballast, while in Figure 8, which represents the type of construction used in the Eastern part of the city, the ties are farther apart and rest directly upon the I beams of the structure, the rails here being of extra depth and weighing 86 pounds per yard, to allow for the increased distance between the ties. While these methods of construction have accomplished to a considerable degree the object sought, they



FIGURES 7 AND 8.
Roadbed of Berlin Elevated Railway.

have not eliminated the noise as thoroughly as is desirable upon the Union Loop.

PRESENT LOOP STRUCTURE.

The present steel structure of the Union Elevated Railway in Chicago, while well designed from a structural standpoint, shows that little consideration was given to the problem of noise, which makes it very difficult to reconstruct it in such a manner as to apply what is now known regarding sound deadening without costing a great deal more than it would have cost had the subject been given careful consideration at the time of construction.

Figure 9 is a general drawing of a typical loop span comprising latticed deck, longitudinal trusses, semi-latticed girders, and riveted posts; and Figure 10 shows an enlarged tranverse section with detail of floor. It will be seen that the rails rest immediately upon ties which, in turn, are rigidly secured to the upper chords of latticed steel trusses, thus giving the best condition for imparting the hammer blows, caused by the wheels upon the rails, directly to the structure that could have been devised, unless the rails had been placed immediately upon the upper chords or upon a metallic support between the rails and the chords. While this construction is not questioned from a railroad engineering standpoint, for it is well designed, attention is called to it to show some of the difficulties that will be encountered in attempting to modify it so as to deaden the sound to such an extent as may be found practicable. *Were the present structure not in place, I am firmly of the opinion that a concrete structure could be designed and built which would prevent to a large degree the noise now emanating from the present steel structure,* for a cost which would not be greatly in excess of the cost of the present structure, and such a design is shown in Figures 11 and 12; but to change the present structure into one resembling such a form is a difficult and expensive task.

In analyzing the relative merits of different classes of construction, the fact should not be lost sight of *that the noise comes primarily from the trains, and a large part of this noise cannot be eliminated entirely no matter how good the design of the structure,* and the best, therefore, that can be expected is to minimize the noise caused by the operation of the trains, to the greatest possible extent, and prevent it

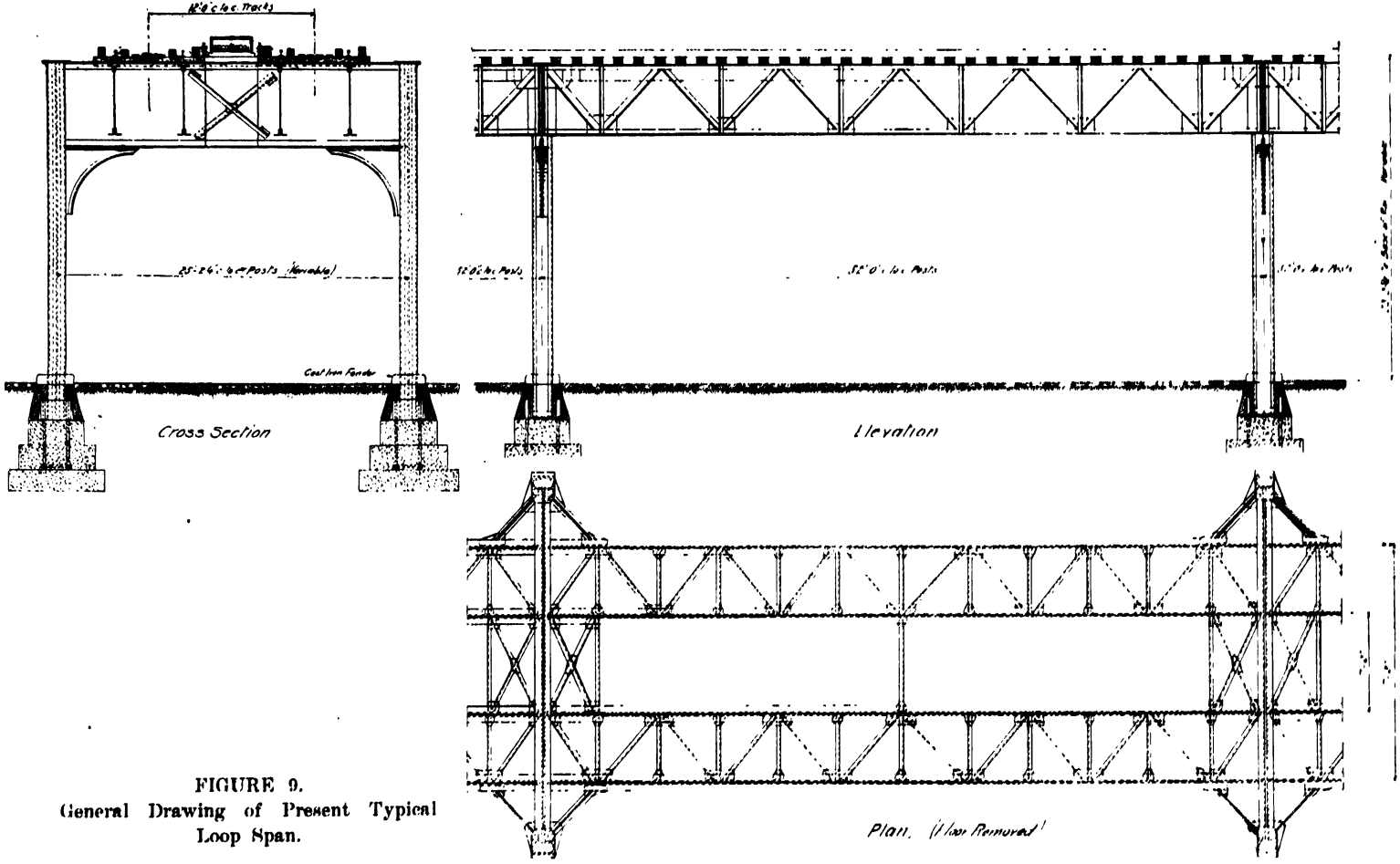


FIGURE 9.
General Drawing of Present Typical Loop Span.

being intensified by the supplemental action of a vibrating or ringing structure.

The structure shown in Figures 11 and 12 would be built of stone or concrete reinforced with steel parts imbedded in the concrete, similar to the methods now becoming so generally utilized in the construction of railway bridges, buildings and other structures.

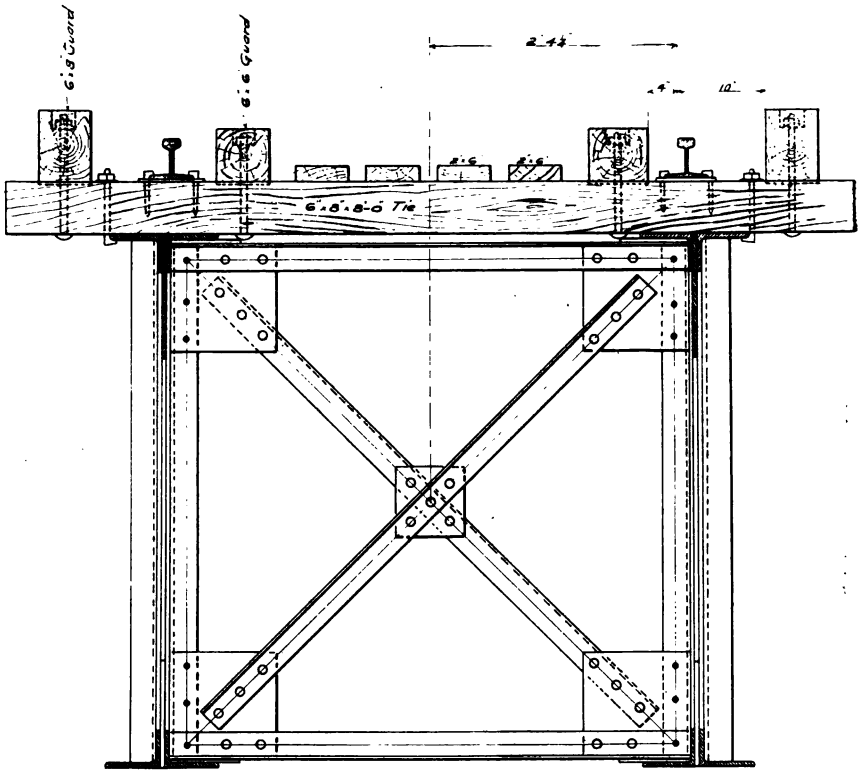


FIGURE 10.
Transverse Section of Present Typical Loop Span.

The use of concrete would eliminate almost all of the difficulty encountered with the present structure due to vibration, and if, in addition, the structure were carried up solid on each side of each track to a point slightly above the bottoms of the cars as shown, the noises produced by the wheels upon the joints and by other working parts of the train would be largely confined to the space underneath the train, and would to a certain extent dissipate themselves and be pre-

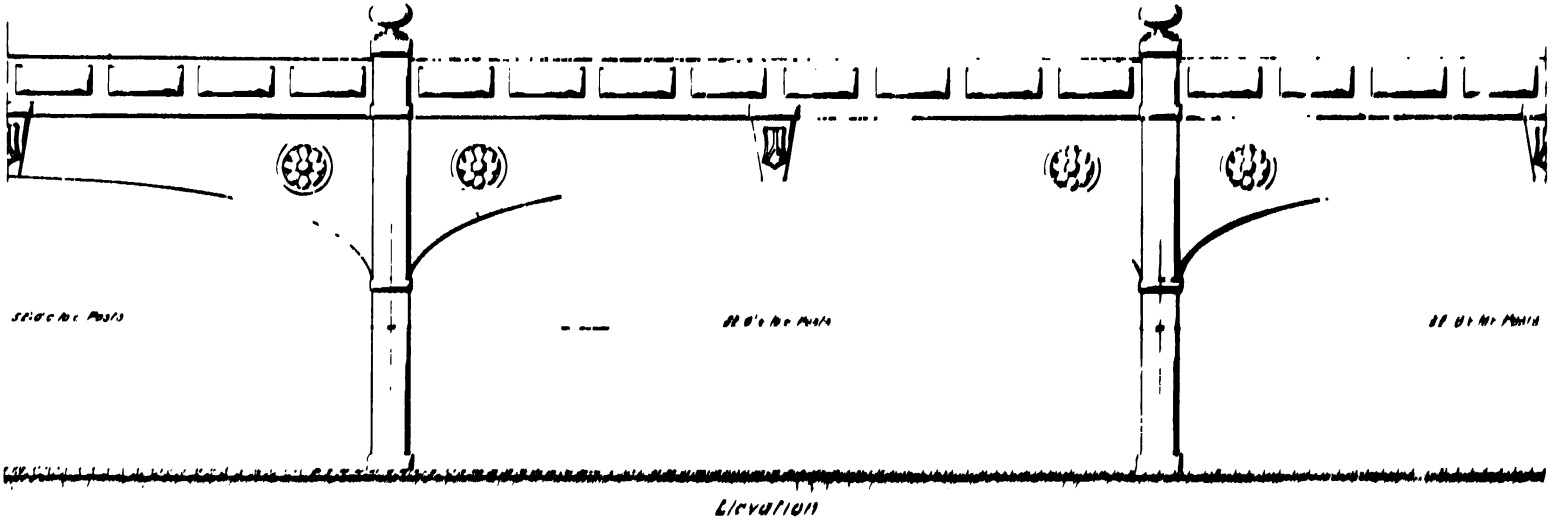


FIGURE 11.
Elevation of Suggested Concrete Structure

vented from being immediately transmitted in a horizontal plane to the sides of the tall buildings on each side of the structure, thence upward, to the annoyance of the occupants of the upper stories as at present. This class of construction would be objected to by the operators of the road, owing to the fact that it would introduce difficulties in removing ties; but in answer to this it may be said that the underground

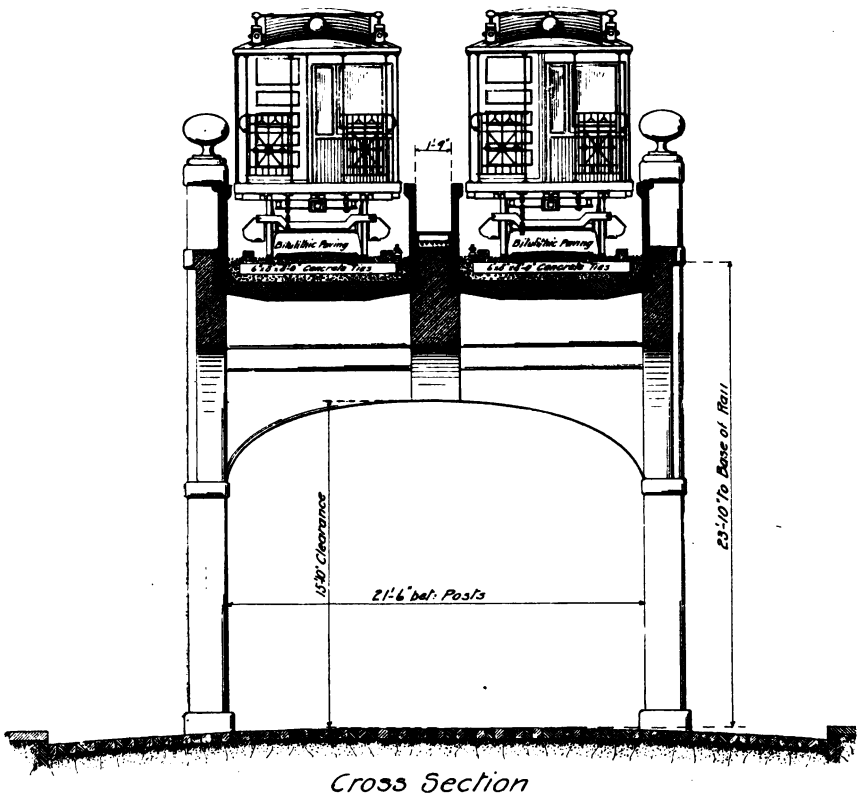


FIGURE 12.
Transverse Section of Suggested Concrete Structure.

railroad of New York (the latest to be constructed), as well as the Berlin Elevated Road and others, have at the present time this objection in a greater or less degree, so that it should not be considered prohibitive if, by its adoption, other advantages could be gained.

Furthermore, the ties on an elevated structure should last many years and the use of concrete steel ties, similar to those

now beginning to be used in steam railway service, would almost entirely eliminate this objection, as they would seldom, if ever, have to be renewed.

Since it would be manifestly unjust to ask that the present loop structure be removed, and thus permit the erection of a design of this character, the problem then is how best to modify the present design so as to reduce the noise to the greatest possible extent without making the cost prohibitive.

There are four primary causes of the noises of the Loop, which are as follows:

1. Imperfect track construction.
2. Imperfect rolling stock.
3. Imperfect roadbed.
4. Defects in structure
   a. Elasticity of the steel;
   b. Lack of rigidity.

IMPERFECT TRACK CONSTRUCTION:

The track when built in 1895 was laid with 80-pound steel rails upon light tie plates, and provided with all necessary special work for operating the trains in and out of the Loop, and so long as the joints of the track remained new and in good condition the noise was not excessive, after the inequalities incident to the opening of a new line of track had worn off, except at the junction points and on crossovers where many frogs and switches were necessarily placed. As the track became worn and the joints hammered, the noise began to increase, and it has continued to increase until the present time, when it is almost unbearable in certain places and especially at the junction points. The present condition of the track is largely due to the failure of the tie plates which proved to be too light for the duty imposed upon them.

As the hammering of the wheels over the joints is the chief source from which noise is imparted to the structure, it is of vital importance that these joints and the entire track be built in as thoroughly first-class manner as possible, and *maintained in this condition.* It seems almost impossible to procure a type of joint over which a heavily loaded wheel will pass without imparting to the rail a blow sufficient to produce sound of considerable magnitude, and in time cause a hollow place in the rail upon which the wheel strikes after leaving the joint.

I have given careful attention to the rail and joint ques-

tion, and believe that the most practical thing to do under the circumstances, in view of the fact that the present rail is badly worn and would have to be renewed before experiments with any new type of rail could be conducted, during a sufficient length of time to determine its practicability, is to use the American Society of Civil Engineers' standard section, rerolled steel T rail, weighing not less than 80 pounds to the yard, having its ends cut at an angle of about 40 degrees, and provided with some first-class joint of the bridge type, such as the Continuous, the Weber, or other equally as good joint. A bridge type of joint is one which allows the ends of the rails to be jointed midway between two ties and the joint itself extends from tie to tie, thus bridging the space between the ties and forming a support for the open rail ends. Figure 13 represents such a joint as seems best to adopt under the circumstances. This joint is not new and has been used in different forms by various railroads, and especially by the Lehigh Valley Railroad, where it was known as the Sayer joint, for a period of about twelve years, and to a certain extent by the Buffalo, Rochester & Pittsburg Road. While it has been abandoned by the former road, due probably to the fact that the advantages gained in steam railway service were not considered by the management sufficient to pay for its increased cost, I believe it to be the most practical thing to adopt in this case at present, for, by its use, it will be possible for the Union Loop Company to equip its road during the coming summer with new rail and thus at once eliminate a large part of the present noise. If this type of joint is used, the rails should not be over 45 feet in length, on account of expansion difficulties. It is important that the joint be made with shoulders on the rails as shown, thereby removing the sharp points.

If there were sufficient time to secure special rails, there is one other type of joint which I believe would do good service. This is known as the scarf joint, shown in Figure 14, and is the standard joint used by the Prussian State Railways for a number of years, and at present used on the Berlin Elevated Road. In its best form, however, it necessitates a specially rolled rail, as it will be noticed that the web is eccentric or off-center of the rail, this construction permitting the rails to be alternated and allowing the webs to lap at the joints, thereby making a stiff, substantial joint,

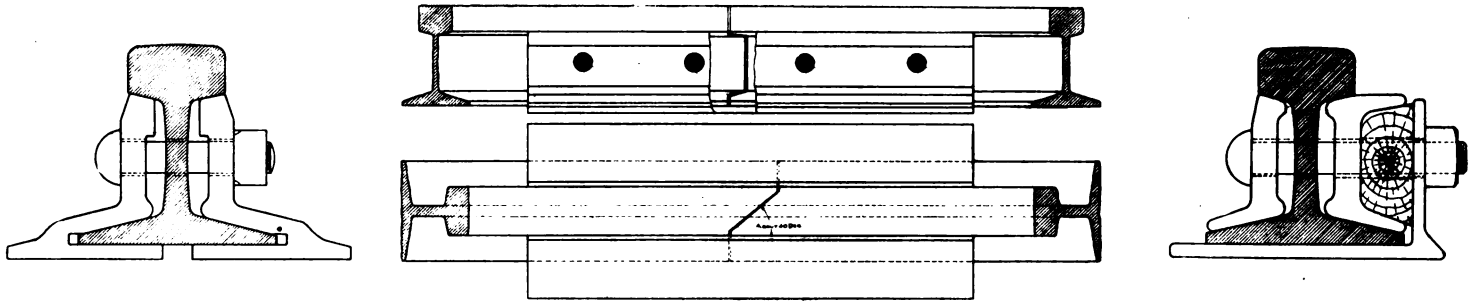


FIGURE 13.
Showing Mitred Joint.

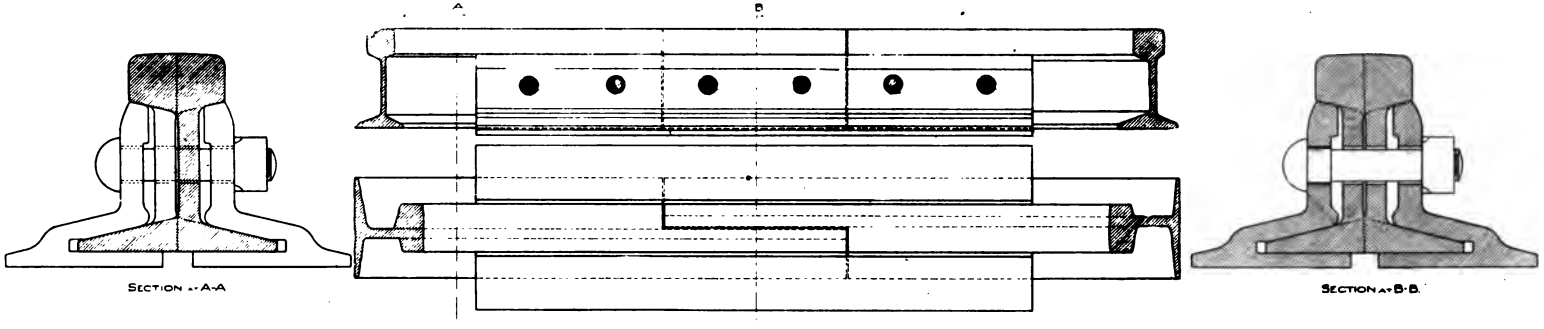


FIGURE 14.
Showing Scarf Joint.

and, at the same time, providing a practically continuous rail for the wheel when passing the joint. It is this form that is used on the Berlin Road and is there known as the Haannann-Vietor rail, after the patentees.

All "special work" not absolutely necessary for the proper operation of the trains should be removed, and worn special work now in place (and ultimately *all* the present special work) replaced with the best and most improved type of manganese steel special work, which, although very expensive, lasts so much longer than ordinary special work that, under the conditions existing on the Loop, it is advisable to use it.

All frogs should be of the movable point type where conditions will permit or of a type which will offer as nearly a continuous rail as practicable for the rails over which the wheels are passing.

In order to make the rail and its support a unit all rails should rest on large and heavy tie plates and be secured to the ties by means of screw spikes or otherwise in such a manner as to prevent the rattling of the rail and plates, *and be maintained in this condition.*

IMPERFECT ROLLING STOCK:

The rolling stock in use on the Union Loop consists mainly of rather light cars with open running gear. Since a large part of the noise proceeds from the running gear, it is important to apply some corrective for this either on the cars or on the structure. Unless the railroad companies will maintain this apparatus in good condition and thereby prevent much of the present noise from this source, some method of enclosing the entire truck, including the wheels, with a light casing of sound deadening, non-combustible material, such as asbestos sheeting, should be tried. This casing should come as close to the guard rails as practicable and clear the third rail, so as to intercept as much of the noise from the wheels as posible. It should have a bottom, and the sides should be hinged to permit inspection.

A truck casing of this type should, to a considerable degree, smother the noise due to brake beams and shoes, defective gears, rattling of bolts and rivets on trucks, etc., which is particularly annoying at times, and in a large part that resulting from the impact of the wheels on the rails. From a railroad standpoint this is a very objectionable thing

to do, for the reason that inspection of the truck and motor parts would be made more difficult and the capacity of the electric motors would be reduced owing to their enclosure. Careful inspection and the prompt renewal of all defective and badly worn parts would largely remove this source of noise and, by adopting side walls on the structure as hereinafter described, the noise from the same would be rendered less objectionable.

The Northwestern and Chicago and Oak Park Roads use single motor cars on their trains, which method of operation imposes upon four sets of motor gears the entire duty of accelerating any train, no matter how heavy. This results in excessive gear noise on heavy trains, which could and should be eliminated by the adoption of the multiple unit system, which provides each car with its own motors and thereby imposes less duty upon individual gears. Furthermore, the average speed of the trains could be increased by its adoption.

The latest types of cars used for intramural transportation, such as those recently put into service in the subway by the Interborough Company of New York, are provided with sound deadening material in the hollow spaces of the floors and sides. There are several fire proof substances that can be used for this purpose, and all new equipment purchased by the elevated roads of Chicago should have all hollow places filled with some such material. Such of the present cars as have no sound deadening material in them should have the hollow spaces filled with mineral wool, asbestos or some other light, non-combustible material.

The present cars and trucks should be put in first-class condition and kept so, and *all future cars should be equipped with trucks having as few parts as practi able.*

The relief opening of the triple valves of the air brakes should be provided with some device for muffling the noise of the escaping air when the brakes are released and thus prevent the sharp whistle now common to some of the cars. This can often be accomplished by changing the size of the orifice.

IMPERFECT ROADBED:

As has been previously pointed out, the roadbed of the present structure, though satisfactory for railroad operation, is defective from the standpoint of sound deadening, and in

order to remedy this defect as far as practicable some type of ballasted floor must be used. This might involve the reinforcement of the Loop structure to provide for the added weight, and this reinforcement governs the selection of the type of floor to be adopted. Considerations of cost, maintenance, interruption of traffic and cutting off the light in the streets below, as well as the difficulties attending the alteration of the existing structure, enter into the problem.

Ballasted floors have been used in this country, and especially in the vicinity of Chicago, by different steam railroads in crossing streets on viaducts, the ballast generally being supported on steel trough plates or I beams with steel plate decking. In some instances creosoted plank has been substituted for the steel decking, and in some types the ballast has been omitted altogether, as in the case of the first track on the New York Central viaduct.

In order to compare the various types of floor construction, six such ballasted floors applicable to the Loop are shown on Plate VII, designated as Types A, B, C, D, E and F. These types have all been designed to support a single track only, leaving an open space between tracks for the feeder conduit and third rails, except at crossings, turnouts and junction points, where the floor would extend across this space. All floors have been figured for 12 inches of broken stone ballast, weighing 140 pounds per cubic foot, and providing for 6 inches of ballast under the ties. Types A and B are what may be termed ballasted steel floors. Type C is a ballasted concrete arch floor, and type E a ballasted concrete steel floor resembling the latest type adopted by steam railroad companies for bridges. All of these are "solid" floors—that is, they form a continuous decking under the track. Type F is a type of open ballasted concrete steel floor.

The effect of the ballast as used in these various types would be a cushioning of the rails, and a reduction of the impact due to the cars, improving the riding qualites of the track, reducing the noise and increasing the durability of the structure. By carrying the ballast up and around the rails the noise due to the singing or humming of the rail would be greatly reduced.

In respect to cost, Types A and B involve drilling of many holes and much field riveting; Type C likewise involves such

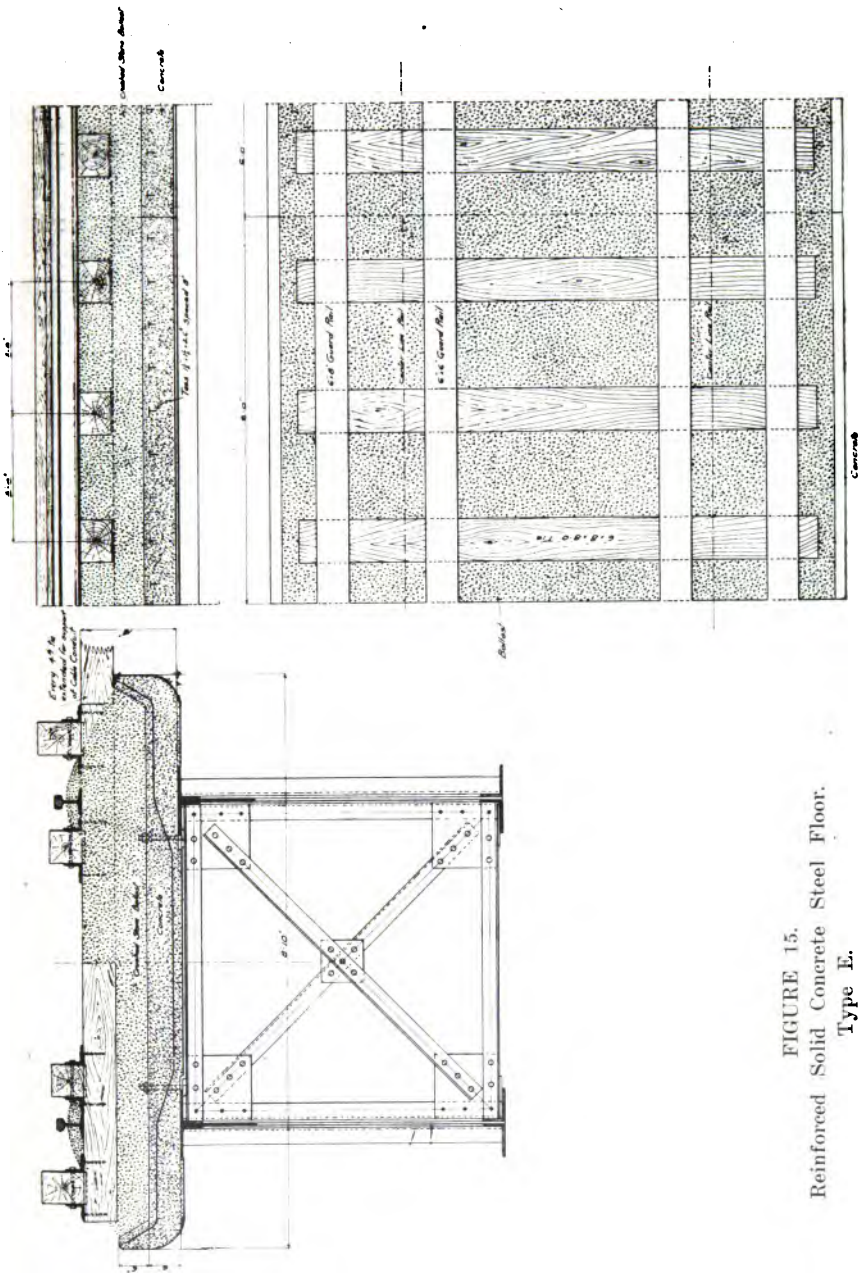


FIGURE 15.
Reinforced Solid Concrete Steel Floor.
Type E.

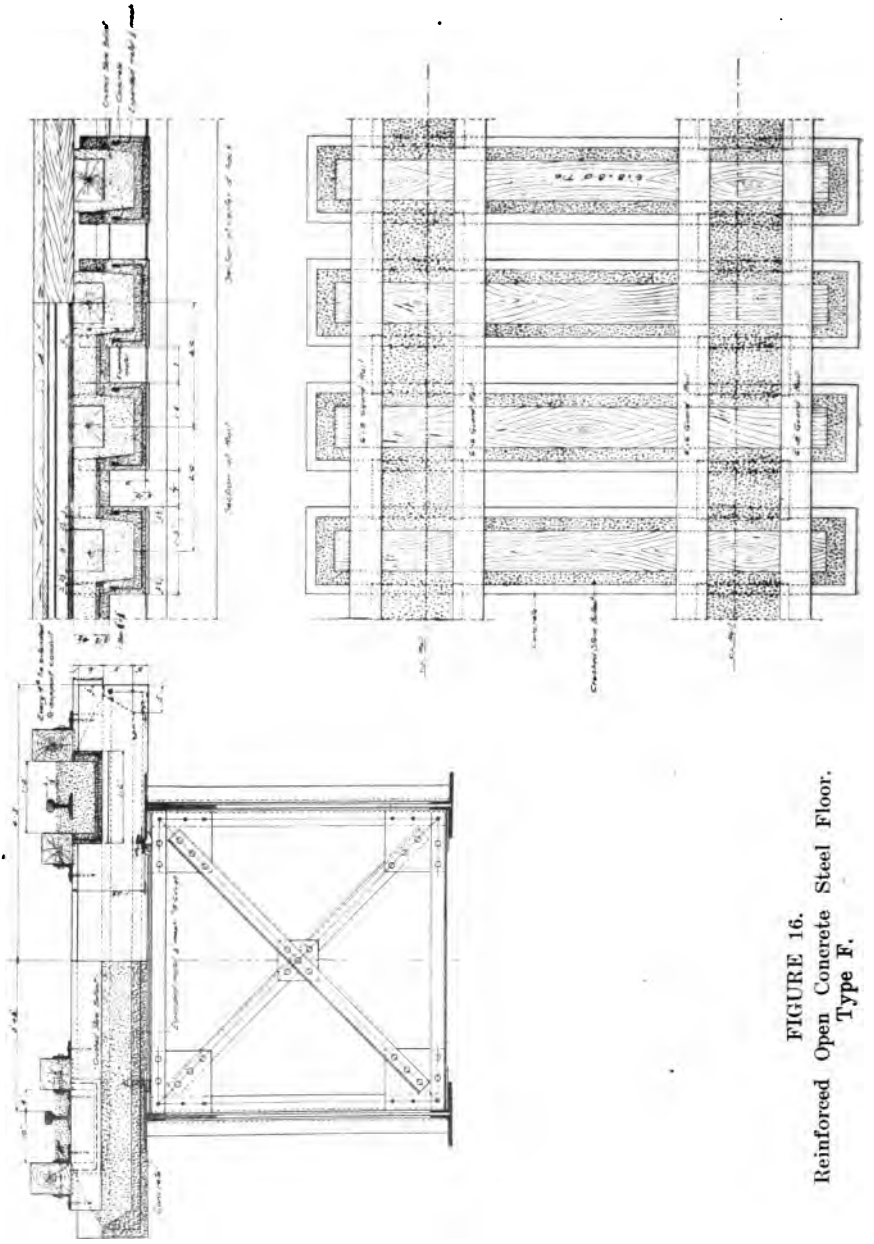


FIGURE 16.
Reinforced Open Concrete Steel Floor.
Type F.

work, but to a less extent, the gain, however, being offset by the cost of the forms required for the concrete arches; type D has but little field work, but in order to insure durability the timber must be treated, which increases the cost and removes the main argument for its adoption; Types E and F are the cheapest floors both in first cost and maintenance.

Experience in the application of ballasted floors to railroad bridges has shown that the track maintenance has been reduced to such an extent that the saving is more than sufficient to pay the interest on the increased investment, made necessary by its adoption.

Where the weight of a floor is not excessive, such as Types D and F, it is probable that the reduction of impact, due to its distribution by the ballast of the floor, would so far reduce the overstress in the members of the present structure as to make its reinforcement unnecessary, although this would somewhat reduce the present factor of safety.

The wooden ballasted floor similar to Type D is now in experimental use on a section of the Boston Elevated Railway, with marked effect toward deadening the sound.

The ballasted steel floors are objectionable because they add to the amount of metal in the structure. This not only increases the noise due to the steel in the structure itself, as will be explained hereafter, but it likewise adds to the cost of painting and maintenance. Steel thus used in a ballasted floor is exposed to deterioration from the water, oils and greases which find their way to the bottom of the ballast.

The concrete floor, on the other hand, is free from these objections, being, in the first place, practically inelastic, and therefore almost noiseless in itself, and, secondly, being proof against deterioration from any of the agencies herein referred to. Type E would probably be made in six-foot sections weighing about 4,000 pounds each, and is adapted to be constructed in any convenient shop near the site, allowed to set and erected in place as required. This would avoid all work in the field except placing and setting, and thus greatly expedite the work and reduce the cost. A larger detail of this floor is shown in Figure 15 and a detail of a similar floor with track enclosure added is shown in Figure 18.

Type F, shown in detail in Figure 16, is in some respects an improvement on Type E. While the amount of concrete is about the same, the individual cross troughs weigh only 1,000

pounds each, which facilitates handling and setting. The field work embraces the bolting of the connecting longitudinal troughs to the cross troughs, and the placing of this floor in position would require the least time and therefore involve the minimum delay to traffic. An important advantage of this floor is that there is a 7-inch opening between each cross-trough, which would admit light to the street below and allow snow falling on the structure to be handled as at present. In Types E and F hook bolts would be provided for securing the concrete to the structure.

The drainage of the Type E ballasted floor would be best provided by means of holes at suitable intervals toward which the floor slopes, discharging into ducts carried to the ground at convenient points, while that for Type F would be made through suitable openings in the bottoms of the concrete troughs. The fastening of the guard rails to the ties could be lag screwed or could be effected by means of angle clips bolted to the guard rails and spiked to the ties, as indicated in Figures 15 and 16. There would be no great difficulty in removing the ties in any of these floors, except where side walls are provided, as hereinafter referred to, and in this case openings could be made for the removal of ties if necessary.

The principal objection, aside from its cost, that is usually brought against the use of a solid floor in a city street is the difficulty of removing snow from the track. While it is admitted that this difficulty is more serious with a solid floor than when an open type of floor is used, it is not insurmountable, since the Berlin and Liverpool roads, a portion of the Boston Elevated, and the portion of the New York Central previously referred to, have been successfully operated, and this objection should not be allowed to prevent the adoption of some type of solid floor if it proves efficient in reducing the sound. I am of the opinion that a type of snow plow or snow collecting device could be perfected which would effectually remove the snow by collecting it and carrying it away in case it became necessary to operate the Loop with a solid floor.

The most important characteristic of these floors is their increased weight, as compared with the present floor, the greatest increment being 1,680 pounds per lineal foot of track for Type E and the least 1,080 pounds per lineal foot for Type F. This additional weight increases the stresses in the structure throughout and necessitates its reinforcement to secure

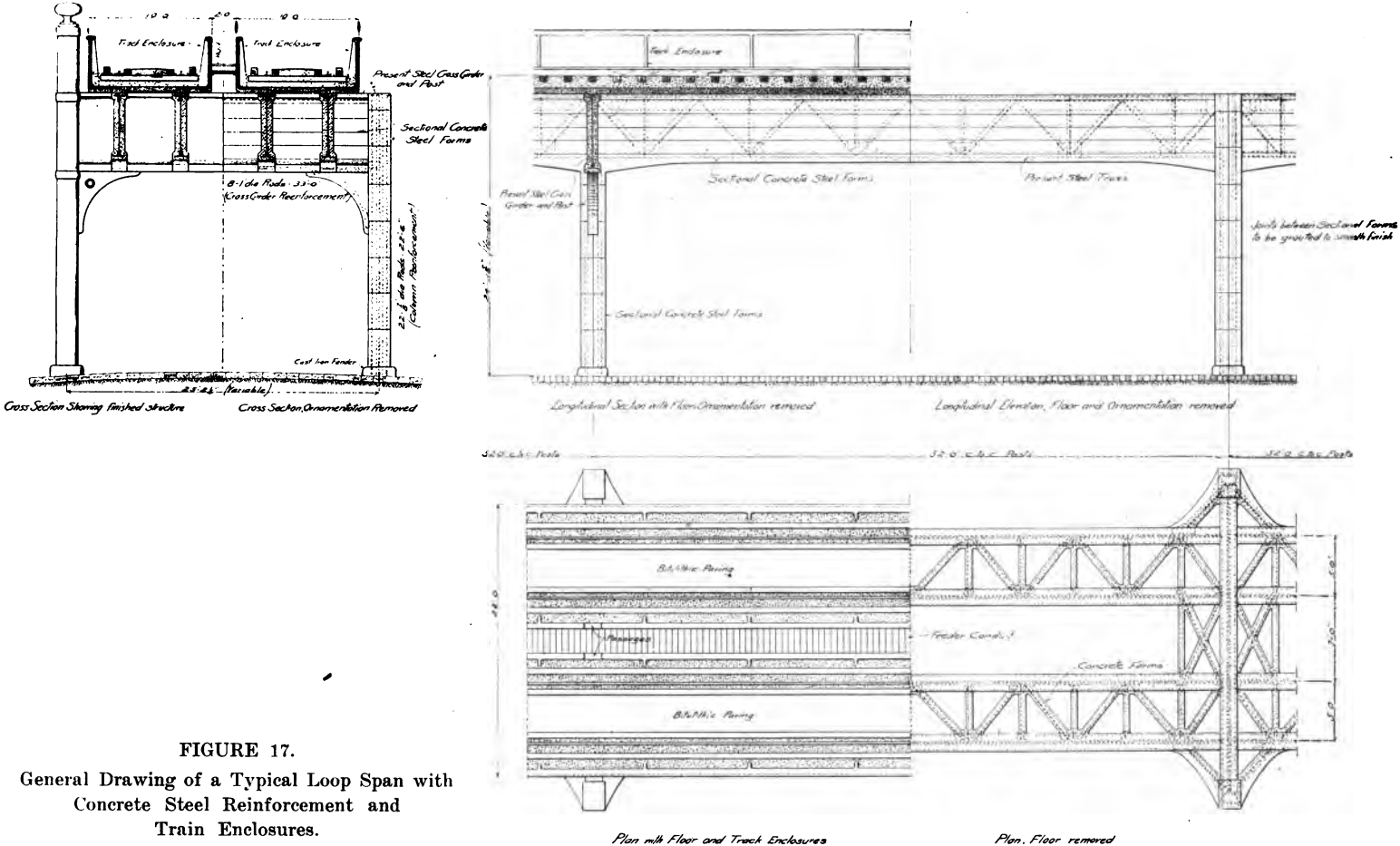

Track Enclosure
Track Enclosure
Present Steel Cross Girder and Post
Sectional Concrete Steel Forms
8-1 dia Rods - 33'-0
(Cross Girder Reinforcement)
22 8 dia Rods 27'-6"
(Column Reinforcement)
Cast Iron Fender
Cross Section Showing finished structure
Cross Section, Ornamentation Removed
Track Enclosure
Present Steel Cross Girder and Post
Sectional Concrete Steel Forms
Present Steel Truss
Joints between Sectional Forms to be grouted to smooth finish
Sectional Concrete Steel Forms
Longitudinal Section with Floor, Ornamentation removed
Longitudinal Elevation, Floor and Ornamentation removed
32'-0 C. to C. Posts
32'-0 C. to C. Posts
32'-0 C. to C. Posts
Bitulithic Paving
Pressed
Bitulithic Paving
Trester Cond.'s
Concrete Forms
Plan with Floor and Track Enclosures
Plan, Floor removed

FIGURE 17.

General Drawing of a Typical Loop Span with Concrete Steel Reinforcement and Train Enclosures.

a corresponding increase of its strength to a greater or less degree depending upon the reduction of impact due to the use of ballast.

On Plate VIII the stresses in stringers, cross girders and posts are tabulated and the method of calculation shown, together with the percentage of overstress and the additional

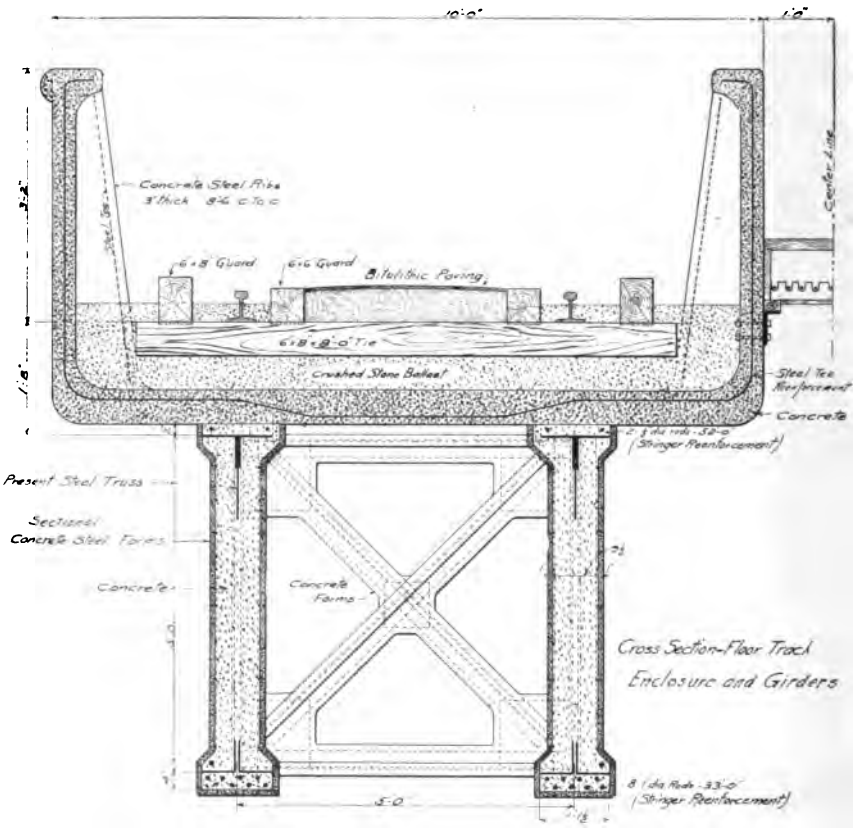


FIGURE 18.

Transverse Section of Typical Loop Span with Concrete Steel Reinforcement and Track Enclosures.

section required. As already stated, the weight of ballast has been assumed at 140 pounds per cubic foot, and this as well as the basis of calculation is noted in the table. It will be seen that the chords of the center panels of the stringers are weak, the greatest overstress being 40 per cent for floor system E and the least 23 per cent for floor system F. In the cross girders

the overstress in the chords of the center panel is 69 per cent for Type E and 45 per cent for Type F. The percentage of overstress in the posts is 24.4 per cent for Type E and 18.1 per cent for Type F. The large overstress in the cross girders is due to the absence of the web plate at the center.

In calculating these tables, a typical 52-foot deck span has been taken, together with a typical cross girder and pair of posts as shown in Figure 9. In estimating the cost, the reinforcement for floor Types E and F has been worked out in detail for the reason that these types seem best adapted to meet the requirements, but for the purposes of comparison the costs of one of the steel floors and the wooden floor are also given, based on the cost of reinforcement required for Type E. The cost in each case has been reduced to lineal feet of double track, and to provide for curves, crossings and junction points has been increased by 25 per cent. From this the total cost of reconstruction of the entire Loop has been deduced.

Two kinds of reinforcement have been calculated, one a usual steel reinforcement and the other a concrete steel reinforcement. The steel reinforcement involves a large amount of drilling, cutting out of rivets and riveting, which must be done in the field under difficulty. The concrete steel reinforcement, on the other hand, requires no alteration in the metal work and can be applied without difficulty. Its greatest advantage over steel, however, is in removing the two elements of cause 3 of Loop noise, as will be referred to hereinafter.

In applying the steel reinforcement, plates are added to the top and bottom flanges of the stringers and cross girders and to the inner faces of the columns, as indicated in Plate VIII, to bring these various members up to the section required by the increased weight of the ballasted floor. These plates would be dimensioned and punched in the shop, but the necessary holes for connecting them to the structure would have to be drilled in the field, as already noted. Special work would be required at the foot of the columns on account of the concrete filled cast iron fenders.

In applying the concrete steel reinforcement, the stringers, cross girders and posts of the structure would be encased in concrete, in which there would be imbedded steel bars wherever necessary to make up the deficiency in section previously referred to, and also to carry the weight of the concrete itself and to support it in place. The steel would require no con-

nection to the structure, thus avoiding to a large extent the difficulty at the fender-castings in case steel reinforcement were used. The adhesion between the concrete and the present steel structure would not be depended upon for the reinforcement but would obviously furnish an additional increment of strength. To still further reduce the noise producing effect of the steel structure, it would be best to encase the laterals and transverse bracing.

The reinforcement should be applied by means of concrete steel forms, which would serve as a facing and remain in place when the work was completed. These forms should effectually prevent any disturbance of the concrete while setting. After setting, and when the bond between it and the steel became established, it is probable that no force which the structure will bear would separate them.

This construction is what is known as a combined concrete steel construction, one of the forms of concrete steel design which has been tried in practical railroad work by competent engineers and which is generally credited with possessing greater durability than steel. As applied here, it has a precedent in the reinforcement of old girders on the Wabash Railroad, which is carried out on somewhat similar lines. In various forms it is successfully used in floor systems and bridges of the C. B. & Q., the C. & E. I. and the C. & W. I. Railroads, as well as others, and it seems to have been demonstrated that it does not disintegrate or suffer under the influence of heavy engine loads at high speeds. Under the comparatively light loads and low speeds used on the Union Loop, the concreting in both the floor and reinforcement, if properly done, should outlast the usefulness of the structure itself.

As regards expansion, it is believed that there would be no difficulty in providing for whatever expansion might occur. Steel and concrete expand and contract at about the same rate, but the greater volume presented by the concrete reduces the effect of temperature changes and consequently lessens the actual change in length and simplifies the necessary provision therefor. Likewise the deflection of the steel girders is greatly reduced by the presence of the concrete. And since experiment and experience both demonstrate that concrete follows steel close to its elastic limit, there is no good reason for anticipating serious difficulty from cracking, provided the concrete is

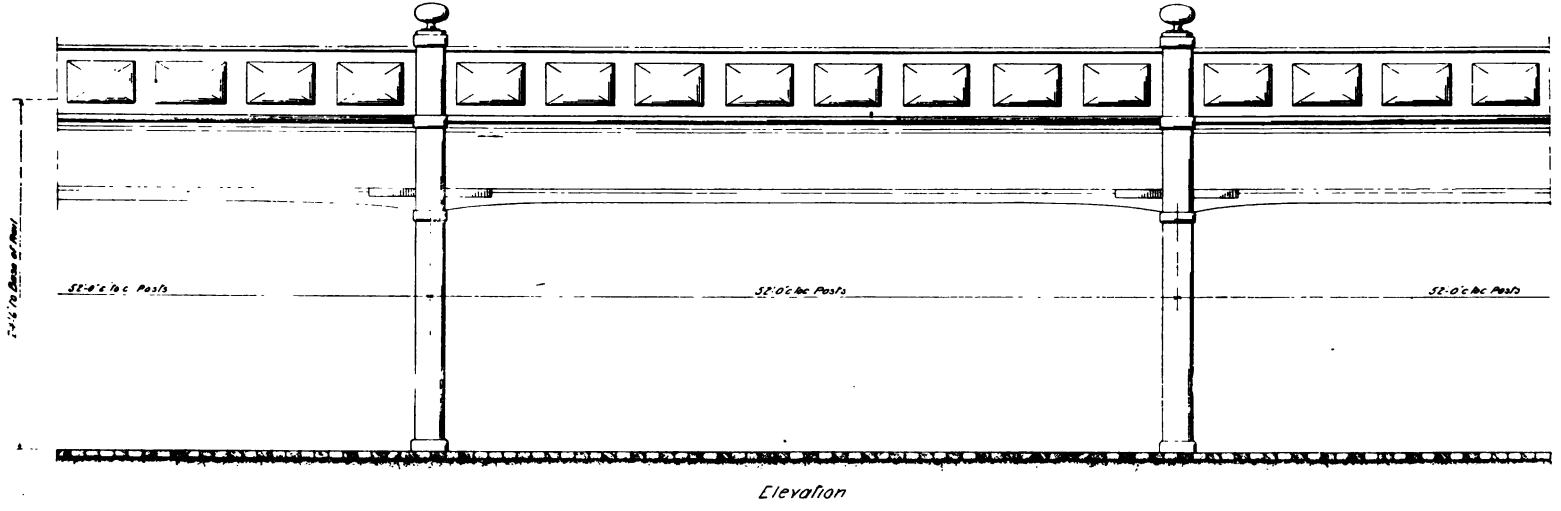


FIGURE 19.

Present Loop Structure Showing Concrete Steel Reinforcement and Track Enclosures Applied with Ornamental Finish.

allowed to set before live load is applied to the particular section under treatment. Aside from its value as a reinforcement and in eliminating the noise of the steel it encases, the concrete reinforcement would serve as a preservative of the present steel structure.

Further advantages of the concrete steel reinforcement are, that it gives a desirable excess of strength and that it lends itself to some ornamentation, while at the same time it allows the enclosure of each track on the sides, as previously suggested. The sides next to the cable conduit would be provided with staggered openings at suitable intervals to allow trackmen to use the cable housing as a refuge platform from trains as at present.

In Figures 17 and 18 is shown the detail of the application of this reinforcement to the Loop structure, while Figure 19 shows it approximating the design shown in Figure 12. The added weight due to the enclosing parts would not require additional reinforcement, as the amount of concrete which it is necessary to apply to enclose the present structure gives an excess of strength, as hereinbefore stated. These enclosures and ornamentation would increase the cost to some extent, but it would still be less than would be required with steel reinforcement. It should also be remembered that these enclosures add to the safety of the structure as regards derailment.

The following table shows the cost of applying the various types of floors discussed, including the two different forms of reinforcement as well as the cost of blocking up the present floor during reconstruction, the necessary track work on the new floor, and a percentage for engineering and contingencies.

APPROXIMATE COST OF STEEL RE-ENFORCEMENT.

Cost Per Foot of Double Track						Total Cost of Additions to Structure
Type	Floor	Re-enforcement	Track and Floor Work	Engineering and Contingencies	Total	
B	$53.30	$33.00	$1.20	$8.75	$96.25	$962,500
D	11.00	33.00	1.20	4.50	49.70	497,000
E	8.00	33.00	1.20	4.22	46.42	464,200
F	6.25	22.15	1.20	2.96	32.56	325,600

APPROXIMATE COST OF CONCRETE STEEL RE-ENFORCEMENT.

Type	Cost Per Foot of Double Track					Total Cost of Additions to Structure
	Floor	Re-enforcement	Track and Floor Work	Engineering and Contingencies	Total	
B	$53.30	$17.30	$1.20	$7.18	$79.00	$790,000
D	11.00	17.30	1.20	2.95	32.45	324,500
E	8.00	17.30	1.20	2.65	29.15	291,500
F	6.25	17.30	1.20	2.47	27.22	272,200

In computing these costs, concrete in floor types E and F was taken at $8.00 and $10.00 per cubic yard respectively, in place; concrete in concrete steel re-enforcement at $10.00 per cubic yard in bulk and $15.00 per cubic yard in forms, both in place. Steel in steel re-enforcement was taken at $65.00 per ton erected and in concrete steel re-enforcement at $45.00 per ton erected. Creosoted lumber was taken at $60.00 per M. in place, ballast at $2.00 per cubic yard in place, rivets cut out at 20c each, holes drilled at 40c each, and rivets driven at 45c each. All prices include contractors' profit. Engineering and contingencies were figured at 10 per cent. Cost of track not included in above figures. If concrete track enclosures as shown in Figures 11, 12, 18 and 19 are used add $90,000 to the totals of Types E and F in Steel re-enforcement and $80,000 to Types E and F in the Concrete Steel re-enforcement.

It will be evident from these tables that Types E and F are the most economical in both cases, and that Type F with concrete steel reinforcement is the cheapest of any of the types shown. If, instead of broken stone ballast, a granulated slag ballast is used, a slight reduction in the cost can be realized. Should a slag ballast weighing 35 pounds per cubic foot be heavy enough to hold the track, and if an overstress of 10 per cent in the stringers is allowable, the cross girders only would have to be reinforced in Type F, as will be seen from the strain sheets. For the loads the Loop carries, and at the speeds they are carried, it is probable that slag ballast would answer. Stretching a point, then, as to the overstress in the stringers and columns, Type F, with steel reinforcement, would require strengthening of the cross girders only, and could, therefore, be applied complete for about $12.50 per lineal foot, or $125,000 for the total structure.

A secondary result of the ballasted floor is the raising of the base of the rail, the minimum increase being 10½ inches in the case of Type F, and the maximum 13 inches in the case of Type B. In Type E the increase is 12 inches. This would necessitate raising the station platforms a corresponding amount, which will involve an additional total expense of

about $5,000 in both cases for the entire Loop.

In order to put in the new floor and the reinforcement associated with it, it would be necessary to block up either one or both of the tracks. To do this, traffic would have to be suspended. By doing this part of the work at night, the interference with traffic would be limited to that period, since the new floor could be put in place after the track had been raised, without stopping traffic during the day.

It is important, however, that sufficient opportunity be given to work effectively in putting in the reinforcement, and in the case of the concrete steel reinforcement the live load should be kept off until the concrete had set, which means a minimum of 14 days and a maximum of 30 days. For this purpose it would be necessary to restrict all trains to one track between stations, taking each track in turn. This would congest traffic, especially during the rush hours, and relief would have to be sought in secondary terminals or otherwise. It is not impractical to build one or two temporary tracks adjoining the present structure, between stations. This would take the traffic off the structure altogether and would greatly facilitate its reconstruction in case it should be found desirable to adopt this method of sound. deadening.

DEFECTS IN STRUCTURE:

The volume of sound given forth by a medium is due to its elasticity, and metals, being the most highly elastic solids, are the best sounding bodies. For the same reason, the duration of sound is greater in metals than in other solids. It is likewise true that an enclosed air space, set in vibration by a sounding body, magnifies the volume of sound according to the laws of resonance.

The present supporting structure of the Union Loop is constructed entirely of steel, which is set in elastic vibration by the passing loads. The various component parts of the structure enclose air spaces more or less confined, which are in turn set in vibration by the molecular motion of the adjacent steel, while the structure as a whole is free to vibrate under influence of the live loads. It will be apparent, therefore, that the Union Loop as built realizes every essential condition for the production of noise.

The concrete steel reinforcement, hereinbefore referred to, does the exact opposite. As a sounding medium it is very low,

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having about one-tenth the sound wave velocity of steel. In encasing the steel it places an inelastic medium between it and the confined air spaces and thus destroys their resonance. It also largely increases the rigidity of the structure and the bulk of material in it, thus destroying all noise due to vibration. For these reasons, the concrete steel reinforcement should completely eliminate the noise created by the structure itself, leaving only such noises as are inherent in the trains themselves, as hereinbefore discussed.

From the foregoing and from observations made during my investigation of this subject, I am of the opinion that the objectionable noises now caused by the operation of cars over the Union Loop can be greatly reduced. Since the Loop occupies the most congested section of the municipality and therefore causes annoyance to the greatest number, and is at the same time the best paying piece of elevated road in the city, its owners ought to be willing to spend sufficient money on its improvement to reduce the noise to as great an extent as it seems reasonable to expect from the adoption of modern engineering methods, even though the accomplishments of the results should prove too expensive for application to lines less favorably located.

While the methods suggested in this report would, in my judgment, prove effective, some of them are to a certain extent experimental and it would therefore be unjust to demand that they be adopted and applied by the railroad company to the entire Loop without their relative efficiencies having first been determined by experiments on short sections of structure, thereby keeping the experimental expense as low as practicable until the best type of construction could be determined by actual demonstration.

My recommendations for reducing the sound upon the Loop and suggested methods of procedure are then as follows:

First. If practicable adopt the plan of increasing the capacity of the Loop shown on Plate IV of Part I of this report. This would eliminate the maximum amount of special work and thus reduce the noise, due to the hammering of wheels on frogs and switches, to the greatest possible degree and at the same time increase the capacity of the Loop to the greatest extent possible by track modification and leave it in the best condition for through routing or Loop operation or both.

Second. If the arrangement shown on Plate IV is not

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adopted, reconstruct in accordance with the plan shown on Plate III, which leaves all tracks at the present grades. Reinforce the structure at all junctions and provide each junction with a solid floor balasted with crushed stone or slag.

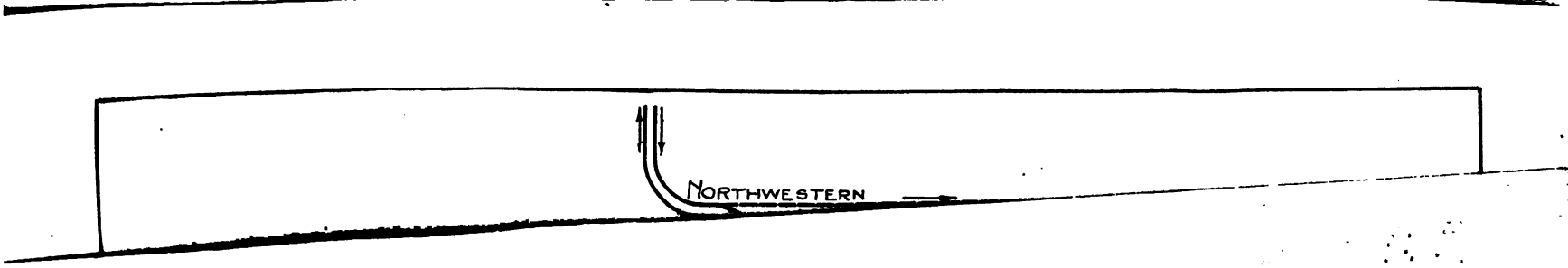
Third. If neither of the above plans are adopted reinforce the present structure at all junctions and provide each junction with a solid floor ballasted with crushed stone or slag.

Fourth. Equip sections of about 300 feet each of the Market Street stub terminal of the Chicago & Oak Park Road over which trains do not now operate regularly with different floors as shown on Plate VII as Types D, E and F, using stone, slag and gravel ballast in different sections and reinforce the structure supporting these sections with the concrete steel reinforcement described in this report and shown by Figures 17 and 18. Operate trains over this stub terminal when so equipped until the relative merits of the different types can be determined. The equipment of this terminal is suggested to prevent interfering with present traffic, but should the railroad company prefer to conduct the trials upon the Loop or elsewhere it should be allowed to do so.

Fifth. After the type of floor and kind of reinforcement which most effectually accomplishes the elimination of noise is determined, the Loop structure between junctions should be reinforced and the type of floor selected applied.

Sixth. *In any event reconstruct the track and special work in accordance with the suggestions contained in this report and maintain the rolling stock, track and special work in first-class condition under rigid inspection.*

Seventh. All changes in the structure should be made in accordance with plans approved by the city and prepared with the special object of sound deadening in view and the experimental and permanent work done in a manner satisfactory to the city.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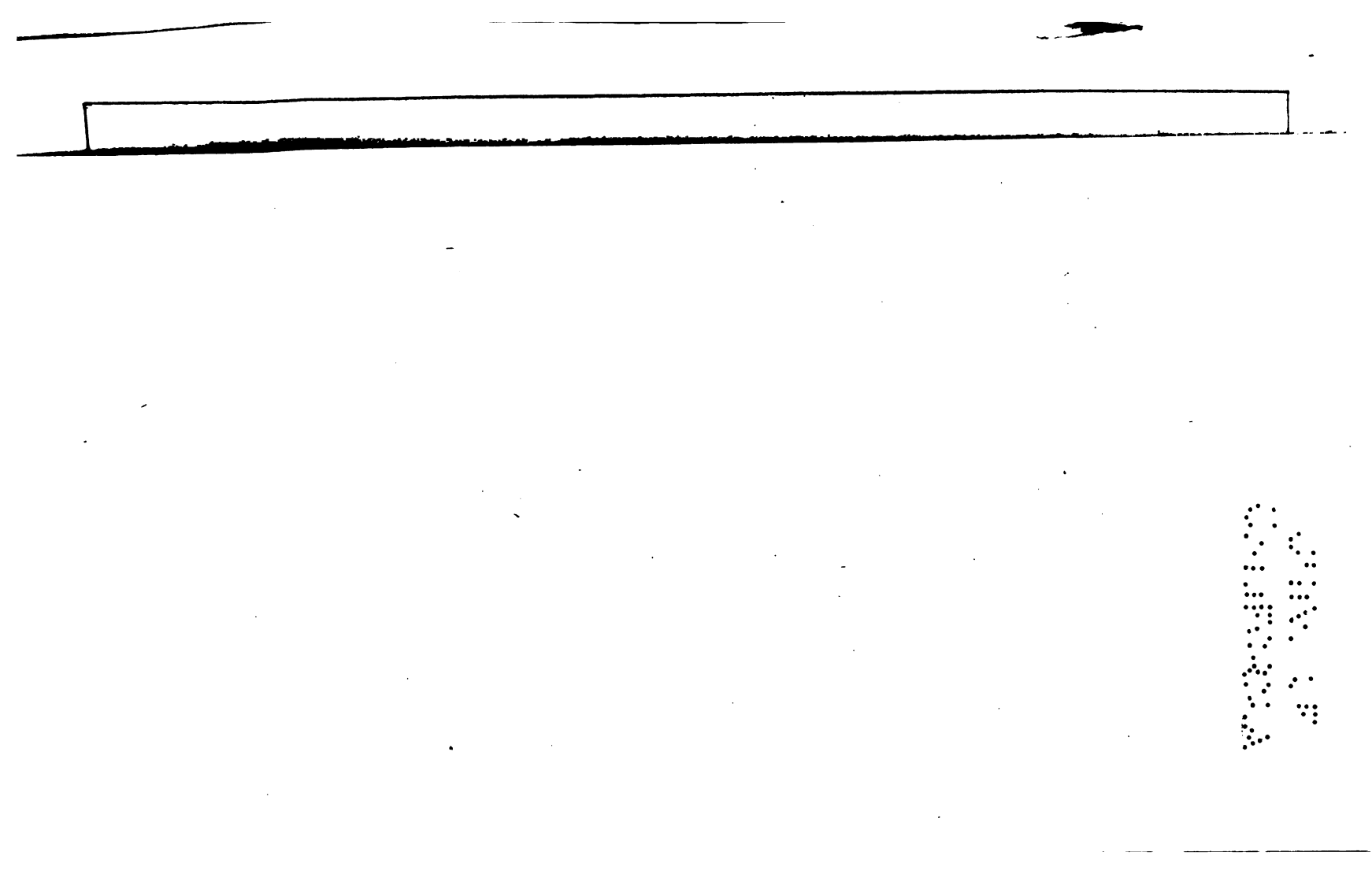

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